DELHI COLLEGE OF ENGINEERING

LIBRARY

Class No.____________________

Book No.____________________

Accession No.____________________

Borrower is requested to check the book and get the signatures on the torned pages, if any.

DELHI COLLEGE OF ENGINEERING
Kashmere Gate, Delhi

LIBRARY

DUE DATE

For each day's delay after the due date a fine of 50 P. per Vol. Shall be charged for books of General Section and Re 1.00 for text books Section.

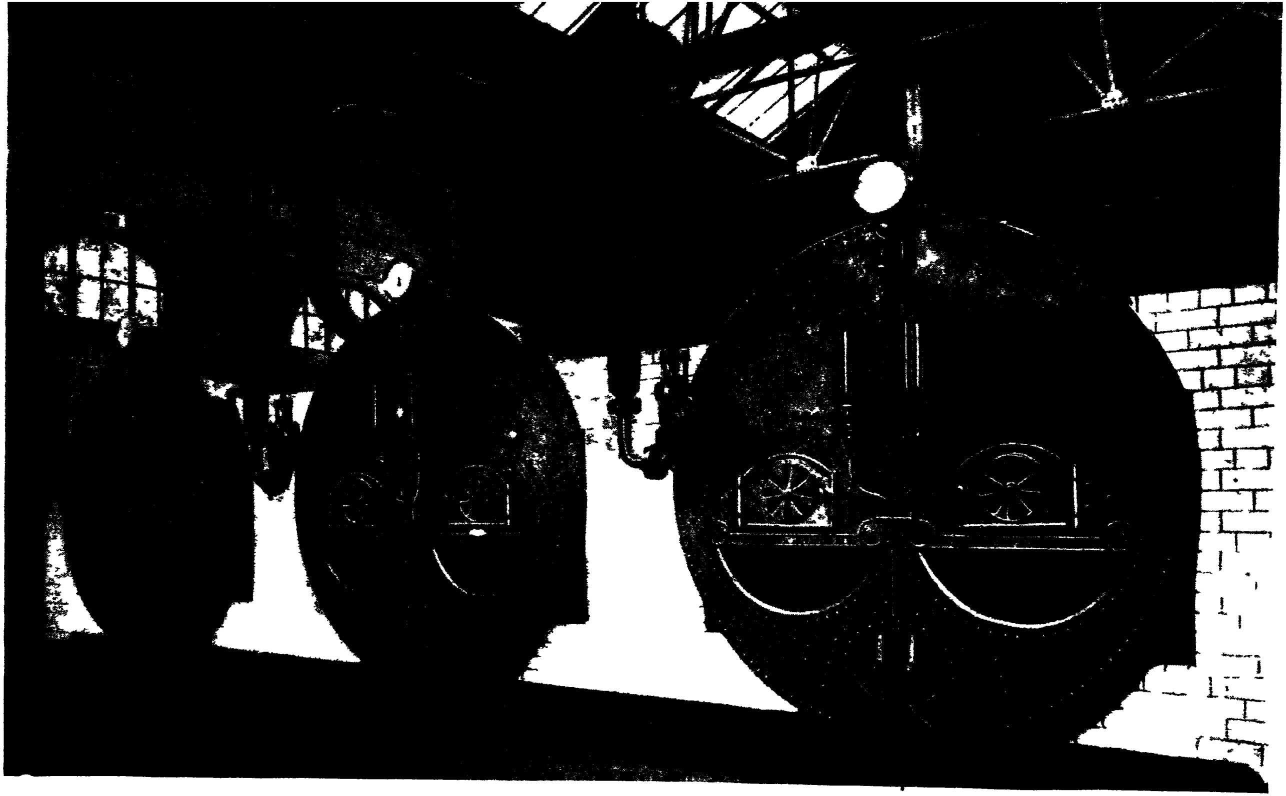
Borrower's No.	Due Date	Borrower's No.	Due Date

THE

WORKS' MANAGER'S HAND-BOOK

OF

RULES, FORMULÆ, TABLES, AND DATA
FOR CIVIL AND MECHANICAL
ENGINEERS, ETC.



Three Lancashire Boilers, 30 ft. × 7 ft. 6 ins × 120 lb per square inch w p, installed at a Munic [illegible]

[*Frontispiece*

WORKS' MANAGER'S HAND-BOOK

OF

RULES, FORMULÆ, TABLES, AND DATA

FOR

CIVIL AND MECHANICAL ENGINEERS, MILLWRIGHTS,
POWER USERS AND BOILER MAKERS;
TOOL MAKERS, MACHINISTS, AND METAL WORKERS;
IRON AND BRASS FOUNDERS,
ETC., ETC.

In Six Sections:

I.—STATIONARY AND LOCOMOTIVE STEAM ENGINES, GAS ENGINES.
II.—HYDRAULIC MEMORANDA: PIPES, PUMPS, WATER-POWER.
III.—MILLWORK: SHAFTING, GEARING, PULLEYS.
IV.—STEAM BOILERS, SAFETY VALVES, FACTORY CHIMNEYS.
V.—HEAT, WARMING AND VENTILATING; MELTING, CUTTING,
AND FINISHING METALS; ALLOYS AND CASTING;
WHEEL-CUTTING; SCREW-CUTTING.
VI.—STRENGTH AND WEIGHT OF MATERIALS;
WORKSHOP DATA, &c

BY

W. S. HUTTON

NINTH EDITION REVISED AND ENLARGED

BY

E. PULL

Chartered Mechanical Engineer, Chartered Marine Engineer,
R.N.R., M.I.Mech.E., M.I.Mar.E.

LONDON
THE TECHNICAL PRESS LTD
5 AVE MARIA LANE, LUDGATE HILL, E.C.4
1938

MADE IN GREAT BRITAIN

PRINTED BY THE LONDON AND NORWICH PRESS LIMITED
ST GILES WORKS, NORWICH

PREFACE

THIS book was compiled by the late Mr. W. S. Hutton from notes, rules and data collected for use in his business as a Civil and Mechanical Engineer. A considerable proportion of the data is based upon practical experience and is not to be found in the ordinary text book or elsewhere without difficulty.

The range of subjects, as will be seen from the list of contents, is most extensive, and in order that the various rules can be readily understood and used by all classes of readers, algebraical formula have been reduced to the minimum.

It is essential that the Works Manager should have available for easy reference a mass of information relating not only to Mechanical Engineering, which in itself is a very wide subject, but also to various branches of industry associated with mechanical engineering, and it is probable that he will be more successful in obtaining the particulars he requires from this book than from any other single volume of equal cost.

Every endeavour has been made to present the information as clearly and concisely as possible. Many of the notes and tables have been brought into line with modern practice, and some forty pages of new matter have been added.

E. P.

WICKFORD, ESSEX.

CONTENTS

SECTION I

STATIONARY AND LOCOMOTIVE STEAM ENGINES, GAS-PRODUCERS, GAS ENGINES, OIL ENGINES, ETC.

PAGE
work 3
of machines 3, 4
d horse power 3—5
d weight of men and animals 4, 5
e to traction 4, 5
ower 5
horse power 5
orse-power 5
meters or Friction Brakes 5, 8
icator and Indicator Diagrams,
on 9, 11
of steam effective pressure, and
ate pressure 15
able 16, 17
of steam used by an engine 17
worked expansively 17, 18
olic logarithms, table of 18
ation in steam cylinders 19, 20
istons and valves 20
e and Compression 20
ing 21
essure 21
f expansion 21
absolute terminal pressure 21
al working 22
jackets 22, 23
ent of the piston 23
ent of the slide valve 24
f valve 24
valve . 25
lide valves . . 25, 26

PAGE
Relief-Frame 27
Eccentric, Throw and advance of 27, 28
Steam-ports and passages 28, 29
Engine governors, ordinary, rules and data for 29, 31
Spring governor and cross armed governor
Governor with centre-weight 32, 33
Shifting eccentric governors 33, 34
Proportions of high pressure non-condensing stationary engines 34—50
Flywheels 53
Proportions of horizontal high-pressure condensing engines 54—60
Compound engines, rules for 60, 65
Triple expansion engines 65
Friction of crank shafts 66
Locomotive engines 66
Adhesive power of locomotives 66
Train resistances 67
Tractive power of locomotives 67
Rules and data for locomotives 67—71
Power of locomotive engines 71
Single and coupled locomotives 72
Great Western Railway locomotive 72
Compound locomotive engines 73
Tests of compound locomotive engines 73, 74
Valve gear, various 75—78
Suction gas producers 79—81
Gas engines . . 82—85
Oil engines . . 86

SECTION II

HYDRAULIC MEMORANDA, PIPES, PUMPS, WATER POWER, ETC.

PAGE
ic memoranda 93, 94
of water 94
of cisterns and cylinders 94, 95
nd water supply 95
c water supply 96
water supply 97
rules for 93, 108
pumps and pump-valves 93—101

PAGE
Load on pumps 101, 102
Suction and delivery pipes of pumps 102
Pumps for hot water 102
Force-pumps 103
Air-vessel 103
Calculations for pumps 103
Capacity of a pump 103
Gallons of water delivered per stroke 103

PAGE
Actual horse-power of pumps . . . 103
Nominal horse-power of pumps . . . 103
Effective work of pumps . . . 104
Diameter of pumps . . . 104
Length of stroke of pumps . . 104
Centrifugal pumps . 104
The hydraulic ram . . . 104, 105
Efficiency of hydraulic rams . . . 105
Speed of pumps 105
Proportions of cocks . . . 105
Weight of water and load to be overcome in pump-barrels . . . 106
Quantity of water delivered by single, double, and treble barrel pumps . 107
Quantity of water delivered at each stroke of a pump 108
Strength of steam and water cylinders, pipes and tubes of various metals 109
Thickness of metal for pipes . . 109
Bursting pressure of pipes . 110
Cast-iron socket-pipes for water . 111
Weight of socket-pipes for water 111
Weight of flange pipes . 111, 112
Weight of pipes and cylinders, rules for the . . 112
Contents of pipes, rules for 112
Thickness of metal for cast-iron gas-pipes, rules for . . 112
Contents of pipes and wells . . 113
Pressure of water in pipes . . 113
Injectors for feeding boilers . 114
Water wheels . . 114, 115
Driving power of water . 114
Over-shot and under-shot water-wheels 114, 115
PAGE
Breast and high-breast water wheels . 114
Paddle water wheel, Poncelet's water-wheel 114, 115
Shafts for water wheels . . . 115
Horse-power of water wheels . . 115
Flow of water 115, 118
Flow of water through orifices . . 115
Time required to fill cisterns . . 116
Flow of water over weirs . . . 116
Flow of water in open streams . . 116
The hydraulic mean depth . . 116
Velocity and discharge of water through pipes and channels . . . 116
Loss of head due to friction 117
Bends in pipes, effect of . . 117
Velocity of water in pipes, diameter and inclination, and discharge of pipes, rules for 117
Inclination of drains, sewers, water channels, rivers, and mill race . . 117
Limits of velocity of water . . . 118
Velocity of water at which various substances are carried off . . 118
Turbines, rules for . . 118
Memoranda for calculating the flow of water . . . 118, 119
Discharge of sewers . 119
The hydraulic press . 119, 120
Thickness of metal for hydraulic-press cylinders . 119
Bursting pressure of hydraulic-press cylinders, rule for 119
The accumulator . . . 120
Coverings for steam pipes . . . 120

SECTION III

MILLWORK: SHAFTING, GEARING, PULLEYS, ETC.

PAGE
Toothed-wheel gearing . . 123—145
Wheel gearing, notes on . . . 123
Bevel and mitre wheels . . 124
Form of teeth of wheels . . 124
Proportions of iron-toothed wheels 124
Form of crab wheel-teeth . . 124, 125
Working speed of toothed-wheels . . 125
Number of wheel-arms . . 126
Width of face of wheels . 126
Mortice wheels, proportions of 126, 127
Worm-wheels, proportions of . . 127
Pitch of small wheels, diametral . 127, 128
Angular and circumferential velocity . 128
The centre of gyration . 128
The radius of gyration . 128
Speed of gearing, rules for the . 129
Wheels and pinions . . . 129
Friction and power of wheel gearing . 130
PAGE
Power of spur wheels 130
Power of bevel and mitre wheels . 130, 131
Power of mortice wheels . . 131
Power of crane-gearing . 131
Breaking strain of wheel-teeth . 131
Horse-power of gearing . . . 131
Strain on crane-gearing . . . 132
Double helical toothed-wheels .
Frictional gearing . . 133
Rope-gearing . . 133
Weight of pulleys for rope-gearing 134
Horse-power of rope-gearing . 134
Weight of toothed-wheel gearing 135
Machine-moulded wheels . 135
Weight and horse-power of ordinary cast-iron spur wheels, tables of . 136—145
Friction of shafts 146
Machinery oils 146

PAGE
Resistance due to friction 146
Power absorbed by friction . . . 146
Friction of shafts and shafting on their bearings 147
Shafting . . . . 147—159
Strain on shafting . . . 147
Torsional strength of shafts . . . 147
Safe torsional strength of shafts . 147
Hollow shafts, strength of . . . 147
Hollow shafting of Whitworth's compressed-steel 148
Torsional stiffness of shafting . . 148
Relative strength of metals to resist torsion 148
Size of crank shafts . 149
Nominal horse-power of shafts 149
Nominal horse-power of crank shafts 149
Power of crane shafts 149
Nominal horse-power of wrought-iron, cast-iron, and steel shafts, table of . 150
Actual or indicated horse-power of shafts 150, 151
Pressure of the necks of shafts . . 151
Corners of shaft-necks . . . 151
Crank shafts of engines . . . 151
Distance between the bearings of shafting 152
PAGE
Weight of shafting, with and without collars, couplings, and plummer-blocks 152
Flange-couplings, proportions and weight of 153
Muff-couplings, porportions and weight of 151, 154
Claw couplings and friction-cone couplings 155
Hangers for shafting 155
Plummer-blocks, proportions and weight of 157
Wall-plates for plummer-blocks . . 158
Speed of pulleys, rules for . . . 158
Pulleys and riggers for belts . . . 159
Pulleys with straight and curved arms . 159
Proportions of the arms and boss of pulleys 160
Weight of pulley castings, both whole and split 161
Strong section for rim of pulleys . . 162
Power of belts 162
Rules for belts 162, 163
Weight of leather belting . . . 163
Strength of leather and cotton belts . 163
Transmission of power to long distances by wire-rope gearing . . . 164
Horse-power of wire-rope gearing . . 164

SECTION IV

STEAM BOILERS, SAFETY VALVES, FACTORY CHIMNEYS, ETC.

PAGE
Steam boilers . . . . 167—190
Effect of heat upon water . . 167
Boiling point of fresh water . . 167
Expansive force of steam . . 167
Elastic or mechanical force of steam 167, 168
Saturated steam 168
Superheated steam . . 168
Combustion of coal and evaporative power of fuels 168, 169
Average evaporative power of various fuels 169
Consumption of coal per indicated horse-power in various kinds of engines . 169
Cylindrical steam boilers . . . 169
Boiler shells . . . 169, 170
Longitudinal strain on boiler shells . 170
Tranverse strain on boiler shells . . 170
Length of boilers 170
Cornish and Lancashire boilers . 170, 171
End plates of boilers 171
Gusset-stays 171
Longitudinal stay bolts . . . 171
Internal flue tube 171
Longitudinal seams of internal flue-tube . 172
Diameter of flue-tube 172
Longitudinal expansion of flue-tube . 172
Strengthening flue-tube over the fire . 172
Man-hole and mud-holes . . 172, 173
PAGE
Boiler fittings and mountings . . 173
Boiler setting 173
Staying flat surfaces 173
Diameter of stay-bolts 173
Working steam pressure of stay-bolts 173, 174
Distance of centres of stay-bolts . . 174
Dished ends of boilers 174
Position of feed delivery in boilers . 174
Heating feed water . . . 174
Nominal horse-power of different kinds of boilers 174, 175
Actual horse-power of boilers . . 175
Quantity of water evaporated per hour . 175
Quantity of water evaporated per lb. of coal 175
Heating surface . . . 175
Dome of boilers 175
Quality of plates for Cornish and Lancashire boilers . . . 175, 176
The Galloway boiler 176
To find the contents of cylindrical boilers 176
To find the contents of Cornish and Lancashire boilers 176
Vertical boilers 176
Proportions and weight of Cornish and Lancashire boilers 177
Proportions and weight of vertical cross tube boilers 178

PAGE
Proportions and weight of vertical tubular boilers 179
Proportions and weight of portable engine boilers 180
Proportions and weight of return tube boilers 181
Weight of wrought-iron boiler tubes . 182
Weight of boilers, rules for calculating the 182
Weight of lap-jointed cylindrical boiler-shells 183
Weight of wrought-iron lap-welded tubes 184
Tensile strength of boiler-plates . . 184
Riveted joints, rules for, etc . . 184, 186
Adamson's flanged seam . . 186
Expansion hoop for furnace-tubes . 186
Strengthening ring for furnace-tubes . 186
Bursting pressure of cylindrical steam boilers, rules for the 187
Bursting pressure of spherical shells . 187
Collapsing pressure of boiler flue-tubes, rule for the 187
Factor of safety of steam boilers . . 187
Bursting pressure of boiler-shells, table of 188

PAGE
Water-tube boilers 189
Efficiency and evaporative performance of various steam boilers . . . 190
Safety-valves, rules for . . 190, 195
Area of a safety-valve . . . 191
Direct load upon the valve . . . 191
Lever safety-valves, rules for . 191—193
Springs for safety-valves, rules for . 191—194
Spiral springs . . . . 191—194
Laminated springs for locomotive engines and carriages, conveyances, etc. . 194, 195
Chimneys for factory steam boilers, rules for 195, 196
Horse-power of factory chimneys . . 195
Size and power of factory chimneys, table of the 196
Prevention of scale in steam boilers . 197
Hardness of water . . 197
Proportions and weight of fire-bars . 197
Care of steam boilers, rules for the 198 - 202
Expansion of water by heat . . 202
Sea water, composition of . . . 202

SECTION V

HEAT, WARMING AND VENTILATING: MELTING, CUTTING, AND FINISHING METALS: ALLOYS AND CASTING: WHEEL-CUTTING: SCREW-CUTTING, ETC.

PAGE
Heat . . . . . 205—208
Unit of heat . . 205
Specific heat of solid and liquid bodies . 205
Expansion of liquids and gases by heat 206
Heat-conducting power of metals . . 206
Expansion in length of metals by heat . 206
Radiation, absorption, and reflection of heat 207
Heat transmitted through plates . 208
Heating rooms by hot water . 208—211
Difference in weight of two columns of water at various temperatures . . 209
Length of 4-inch pipe required to heat 1000 cubic feet of air per minute . 209
To find the length of pipe required to heat the air in a building 210
Length of pipe required to warm churches, schools, greenhouses, and various buildings 210
Cooling of iron pipes 210
Rate of cooling by radiation for the same body at different temperatures . . 211
Quantity of coal used per hour to heat 100 feet of pipes of different sizes . . 211
Boiler power for heating by hot water . 211
Quantity of air required to be warmed per minute for various purposes . . 211
Heating rooms by steam . . . 211
Expansion of steam and hot water pipes 212
Ventilation 212, 213

PAGE
Quantity of air required for ventilating purposes 212
Quantity of air required for ventilating apartments, hospitals, buildings, etc. . 212
Space provided for each bed in hospitals and dwelling-houses . . . 213
Ventilation of mines 213
Furnace ventilation 213
Weight of pure air 213
Atmospheric air, increase in volume of, by elevation of temperature . . . 213
Heating water by steam . . . 214
Condensation of steam in pipes . . 214
Refrigerating machinery . . . 215
Cutting metals, and speeds for . . 216
Drilling metals 217
Feed or advance of tool in lathes and planing machines 218
Angle of lathe centres 218
Cutting angle of lathe tools . . . 218
Quantity of work turned out by lathes, planing, shaping, slotting, and drilling machines, etc. 219
Speed of circular saws . 226
Speed of horse-power of wood-working machinery 226
Speed of grindstones 227
Speed and proportion of fans . . 227
Wheel-cutting . . . . 227—229
Screw-cutting . . . . 229—239

PAGE
Screw-cutting, rules for . . 229—232
Screw-cutting, tables of change wheels for . . . . 236—239
Cast-iron and iron castings . . 240, 241
Cast-iron, strength of 240
Cast-iron, testing 240
Cast-iron, various mixtures of metals for casting 241
Brass furnace and brass melting . 242, 243
Strength of copper 243
Strength of and mixtures of metal for bronze, gun metal, brass aluminium bronze, sterro metal, Muntz metal, malleable brass phosphor bronze, non-corrosive bronze, silicium bronze, compressed bronze . . . 243, 244
Bronze and gun metal for bearings 245
Wear-resisting qualities of alloys . . 245
Hot-bearings 245
Light alloys of aluminium . . . 245
Mixtures of metals for bronze, gun-metal, brass and other alloys . 246—250
Strength of alloys and weight of bells . 251

PAGE
Antifriction white metal and other alloys . . . . . . 252—253
Melting points of alloys and metals . 256
Temperature of furnaces, dissolving metals, etc 256
Strength of hot metals, malleability, ductility, and tenacity of metals . 257
Solders, tables of . . . 257—258
Brass finishing, burnishing, etc. . . 259
Blueing, colouring, tinning, bronzing, lacquering, silvering, and japanning processes . . . . 260—264
Hardening, softening, and tempering processes . . . . 264—270
Weight of metal for alloys . . . 270
Proportion of engineer's taps, machine taps, gas taps, and rhymers . 271—273
Hydraulic iron piping and gas piping . 274
Whitworth's standard screws and bolts . 275
Bolts and screws 276
Whitworth's standard screw threads for watchmakers 277
Conducting power of metals for electricity 277

SECTION VI

STRENGTH AND WEIGHT OF MATERIALS: WORKSHOP DATA, ETC.

PAGE
Strength of wrought-iron . . . 279
Testing wrought-iron 279
Admiralty tests for wrought-iron plates . 279
Forge tests, cold and hot . . . 280
Admiralty tests for ship-plates . . 280
Steel boiler-plates . . . 280, 281
Tests for rivets 281
Tests for wrought-iron bridge-plates . 281
Diminution of tenacity of iron boiler-plates at high temperatures . . 281
Effects of re-heating and rolling iron . 281
Breaking strains of ropes and chains . 282
Weight and strength of steel-and-iron-wire ropes and hemp ropes . . 282
Weight and strength of steel, iron, and hemp flat ropes 282
Weight, working load, proof-strain and breaking strain of chains . . . 283
Proportions of the links of chains . . 284
Strength of chains and ropes . . 284
Working or safe load for ropes . . 284
Girders and beams 284
Wood girders 284
Solid-rolled wrought-iron girders . . 285
Box-girders, web and T-girders . . 285
Deflection of girders and factor of safety for girders 285
Solid round beams and girders . . 285
Proportions of rolled girders . . . 286
Hollow beams and angle iron beams . 287
Cast-iron girders 287

PAGE
Proportions of cast-iron girders . . 288
Riveted wrought-iron girders . . 289
Box-girders and rivets for girders . . 289
Steel joists and girders . . 290, 292
Flitch-beams and stanchions . . 293
Weight and volume of metals . . 294
Rules for weight of castings 295—298
Strength of, and safe load for, pillars and columns 299
Proportions of rivets and riveted joints . 300
Strength of riveted joints . . . 301
Proportions of riveted joints of steel . 301
Weight of iron and steel plates . . 302
Weight of bolts, nuts, and washers . 303
Strength of bolts, foundation bolts . 304
Size of Whitworth standard nuts: weight of gas tubes 305
Weight of composition pipes: block-tin tubes and corrugated sheet-iron . 306
Weight of round and square bars, of iron and steel 307
Weight of flat bars of iron and steel . 308
Weight of hoop-iron and of iron-wire and steel-wire 308
Weight of rolled wrought-iron plates and sheet-iron to the B. G. gauge and the imperial wire gauge; and of Siemens' steel plates 309
Weight of sheet-copper and sheet-brass to the new imperial wire-gauge; and strength of aluminium . . . 310

PAGE
Weight of Bessemer steel, rolled steel and gun metal sheet, and of rolled white-metal, lead and zinc sheets, the thickness being measured by the new imperial standard wire gauge . . 311
Weight of a square foot of metals . 312
Weight and strength of iron-wire to the new imperial wire-gauge . . . 313
Weight of angle and T-iron . . 314
Strength of lead pipes . . . 314
Solder required for joints . . . 314
Weight of metal balls: and lead pipes . 315
Weight of lead for pipe joints: weight of angle, tee, and channel steel . . 316
Weight of cast-iron cylinders . 317, 318
Weight of half-circles of cast-iron and of small cast-iron spur wheels . . 319
Weight of circular and square cast-iron plates 320
Weight of bars of copper, brass, lead and zinc 321
Weight of sheet zinc: of tin plates: size of the bore of guns 322
Weight of glass: sheet lead, iron and copper rivets: galvanized iron . . 323
Birmingham and other wire gauges . 324
Weights of metals to the Birmingham wire gauge 325
Weight of plates and tubes of various metals . . . . . . 326—343
Breaking strength and weight of materials and liquids . . 344—349
Power required for machinery . . 350
Cisterns, tanks: pumping water . 351—353
Flow of water and sewage . . . 353
Qualities of various metals . . 355—359
Carbon-steel and nickel-steel . . . 359
Hardness of metals 359
Prevention of corrosion . . 360
Qualities of timber . . 361—363
Workshop receipts and cements . 364—373
Paints; varnishes; colouring drawings . . . . . . 374—377
Gravity; moving bodies; punching and shearing metals . . . 377—379
Contraction of metal in castings . . 379
Depreciation of machinery and factories . 370
Weight, bulk, composition, heat and evaporative power of coal and other fuels 380
Pressure and discharge of gas . . 381
Wind-pressure on structures . . 382, 383
List of minerals 384, 385

PAGE
List of chemical and mineral substances . . . . . . 385—387
Measures relating to building . 387—389
Working loads on, and strength of, building materials . . . 390—392
Horse-power of leather belts . . . 393
Horse-power of single and double belts . 394
Horse-power of balata belts . . . 395
Distance apart of bearings for shafts . 396
Power required for machine tools . . 397
Chain slings safe working load . . 398
Analysis of liquid fuels . . . 399
Cutting lubricants 399
Properties of aluminium . . . 400
Properties of duraluminium . . . 401
Properties of aluminium-magnesium alloys 402
Standard pipe flanges for pressures up to 50 lbs. 403
Standard pipe flanges for pressures up to 100 lbs. 404
Thermal properties of solids . . 405
Physical properties of various metals . 406
Conversion tables for wheel pitches . 407
British Standard Whitworth bolts . 408
British Standard fine screw threads . 409
Standard gas and water pipe threads . 410
British Association threads . . . 411
Threads for copper tubes . . . 412
Formula for gear wheel teeth . . 413
Morse tapers 413
Conversion factors 414
Capacity of round tanks . . . 415
Speed of grinding wheels . . 416
Horse-power for grinding machines 416
Atomic weights of elements . . . 417
Standard taper pins 417
Running costs of A. C. motors . . 418
Properties of nickel bronzes . . . 419
Tapers and angles 420
French measures . . . . 421—422
Decimal equivalents and approximates . . . . . 425—427
Mean temperature of the air at various places in summer and winter . . 428
Annual rainfall at various places . . 429
Rainfall per yard and per mile . . 429
Motor-cars 430
Tractive resistance of motor-cars and other vehicles 431
Patents . . . . . . 432—433
Remedies for workshop accidents . 433—436
The Factories Act, 1937 . . 437—442

INDEX . . . . 443—462

SECTION I.

STATIONARY AND LOCOMOTIVE STEAM-ENGINES, GAS-PRODUCERS, GAS-ENGINES, OIL-ENGINES, &c.

THE
WORKS' MANAGER'S HAND-BOOK

SECTION I.

STATIONARY AND LOCOMOTIVE STEAM-ENGINES, GAS-PRODUCERS, GAS-ENGINES, OIL-ENGINES, &c.

WORK AND HORSE-POWER.

A Unit of Work is equivalent to one pound avoirdupois raised vertically one foot The units of work done in raising a given weight to a given height, are found by multiplying the height in feet by the weight in pounds. The units of work done in raising a weight up an inclined plane, are equal to the work that would be done in raising the weight vertically through the height of the plane.

The Modulus of a Machine is the fraction which expresses the relation of the work done to that of the work applied, or the percentage of the power absorbed which a machine will give out in useful work.

MODULUS OF MACHINES.

Centrifugal-pump, small	·25
Undershot water-wheel	·25 to ·33
Paddle water-wheel	·25 to ·33
Inclined chain-pump	·38
Oscillating pump	·45
Hydraulic-ram—lift 10 to 1 of fall	·48
Centrifugal pump, medium size, low lift	·50
Common lift-pump	·50
Upright chain-pump	·53
Pumps for drainage	·55
Undershot water-wheel	·55
Fire-engines	·57
Endless-chain and buckets lift 9 feet	·58
Bucket-wheel	·60
Breast water-wheel	·60
Turbine, with sluice half open	·61
Pumps for mines and deep wells	·66

Archimedean-screw	·68
Centrifugal-pump, large, low lift	·70
Overshot water wheel	·70
High-breast water wheel	·75
Turbine, with sluice wide open	·75
Hydraulic-ram –lift 4 to 1 of fall	·75
Hydraulic machines—4 to 1	·75
Three-throw pumps	·76
Waterworks pumping-engine	·80

Power and Weight of Men and Animals.—In working a crane-handle, a man can apply a force of 60 lbs. in an emergency with difficulty, or a force of 30 lbs. for a short time with difficulty, or a force of 20 lbs. for a short time easily, or a force of 15 lbs. in continuous work at a velocity of 220 feet per minute; hence the power of a man is $= 15 \times 220 = 3{,}300$ foot pounds per minute, or one-tenth of a horse-power. A soldier on march travels about 30 inches per step, and occupies a front of 21 inches in the rank; the average weight of men is 150 lbs. each; five men can stand in a space of one square yard; the weight of ordinary crowds of people is 80 lbs. per square foot; the absolute force of a man in pulling horizontally or pushing with his hands is 110 lbs.: his lifting power with both hands is 280 lbs., and the greatest load he can support on his shoulders is 336 lbs. A horse will exert a pulling force of 120 lbs. at the rate of $2\frac{1}{2}$ miles an hour during 10 hours. A pony or mule will exert a pulling force of 60 lbs. at the rate of $2\frac{1}{4}$ miles an hour during 10 hours. An ass will exert a pulling force of 30 lbs. at the rate of 2 miles an hour during 10 hours. Each of these animals will carry a load on its back equal to one-fourth its own weight, at the rate of $2\frac{1}{2}$ miles an hour during 10 hours. A horse will draw a load of one ton at the rate of $2\frac{1}{2}$ miles an hour during 10 hours. A pony or mule will draw a load of 12 cwt. at the rate of $2\frac{1}{4}$ miles an hour during 10 hours. An ass will draw a load of 7 cwt. at the rate of 2 miles an hour during 10 hours. These forces are for a straight pull; when animals work by pulling while walking in a circle, their pulling force is only about 60 per cent. of their force for a straight pull; the diameter of the circular path should not be less than 25 feet, and the velocity should not exceed 2 miles an hour. The average weight of a cart-horse is 13 cwt.; a cob, 7 cwt.; a mule, 6 cwt.

Resistance of Carts and Waggons to Traction on Level Roads and Rails.—The resistance to traction in proportion to the whole weight is $\frac{1}{10}$ on fields; $\frac{1}{12}$ on gravel and on broken-stone roads in bad condition; $\frac{1}{25}$ on dry hard turf; $\frac{1}{50}$ on good macadamized roads; $\frac{1}{55}$ on underground tramways with 8-inch diameter wheels; $\frac{1}{60}$ on wood pavement; $\frac{1}{70}$ on good London pavement; $\frac{1}{80}$ on street tramways with grooved rails; $\frac{1}{110}$ on underground tramways with 12-inch wheels on round top rails; $\frac{1}{150}$ on asphalte pavement; $\frac{1}{180}$ on granite tramway; $\frac{1}{280}$ on railways.

The force required to drag a weight on a level firm wood floor without rollers is $\frac{3}{8}$ the whole weight, and with the weight placed on rollers 3 inches diameter, it is $\frac{1}{40}$ of the whole weight.

Horse-power.—A strong horse can travel $2\frac{1}{2}$ miles per hour and work 8 hours a day, doing the equivalent of pulling a load of 150 lbs. weight up out of a shaft by means of a rope. $2\frac{1}{2}$ miles an hour is 220 feet per minute, and at that speed the load of 150 lbs. is raised vertically the same distance, that is equal to 300 lbs. raised 110 feet high, or 3,000 lbs. raised 11 feet high, or 33,000 lbs. raised one foot high per minute. The unit of power is the mechanical force necessary to lift 33,000 lbs. one foot high in one minute; but, in dealing with steam engines, three terms are used, viz., nominal, indicated, and brake horse-power.

Nominal Horse-Power is a commercial term used by makers of engines to denote only the size of an engine without regard to the actual power it will exert.

Indicated Horse-Power. (I.H.P.).—Is the power actually developed in the cylinder. The formula used is.

$$\text{I.H.P.} = \frac{P \times L \times A \times N}{33{,}000}$$

where P = mean effective pressure on piston in lb. sq. in.

L = length of stroke in feet.

A = area of piston in sq. in.

N = number of working strokes per minute.

Mechanical Efficiency.—Is the ratio between the work done by the steam and the work available at the shaft, or

$$\frac{\text{B.H.P.}}{\text{I.H.P.}} = \text{Mechanical efficiency.}$$

Actual Horse-power of Steam-Engines.—To find the actual horse-power. *Rule:* Multiply the area of the cylinder in square inches by the average effective mean pressure of the steam in lbs. per square inch, minus 3 lbs. per square inch for friction; and by the speed of the piston in feet per minute. The product will be the number of foot-pounds per minute which the engine will raise. Divide this product by 33,000, and the quotient will be the actual horse-power of the engine.

Brake Horse-power is the power of an engine measured by a friction-brake, or dynamometer. It represents the effective horse-power, or the indicated horse-power of an engine minus the power absorbed by its own friction.

Dynamometers.—The power of a motor or engine may be measured by absorbing by friction the whole power developed by it, by means of a dynamometer, or friction-brake.

Prony's Brake, shown in Fig. 1, acts by absorbing the power transmitted to it; the friction is balanced by a weight at the end of a lever. It consists of a horizontal lever, having at one end a strap of iron, lined with blocks of wood, which embraces a pulley keyed on the shaft of the motor, and at the other end a suspended carrier for weights. The lever is prevented from rising or falling excessively by stop-blocks. If the reputed power of the motor is known a weight corresponding to that power is hung on the lever, and after the engine is started, the strap is gradually tightened, and the wood is drawn tightly against the surface of the pulley,—which is kept cool by a stream of soapy water. The weight on the lever is increased or diminished gradually until the lever is in equilibrium. When the engine is running at its proper or normal, speed, with the correct pressure of steam, the lever will be raised slightly above its horizontal position; if the lever be raised considerably the power will be in excess of the calculated power, and the weight in the scale must be increased so as to obtain the maximum power.

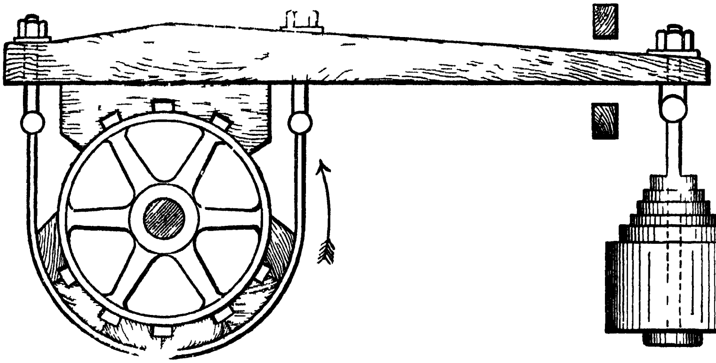


Fig. 1.—Lever Friction Brake.

To find the Dynamometrical horse-power. Rule: Multiply the circumference in feet described by the lever by the number of revolutions per minute and by the weight suspended, in pounds, and divide the product by 33,000.

To find the weight to be used to test an Engine. Rule: Multiply the horse-power by 33,000, and divide by the product of the circumference in feet described by the lever multiplied by the number of

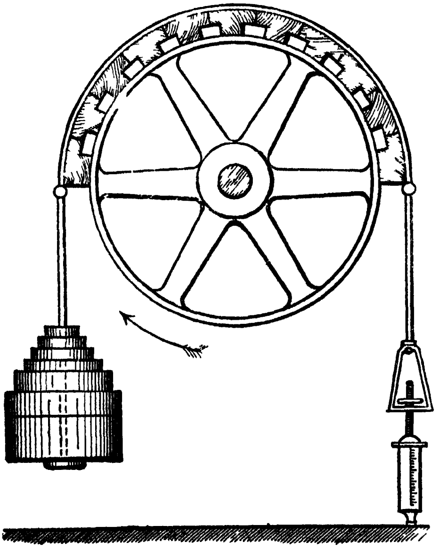


Fig. 2.—Iron Strap Friction Brake.

revolutions. The weight of the lever must either be balanced, or provided for in the calculation.

In using this brake it is difficult to maintain the lever in a horizontal position, or in equilibrium. This form of brake can only be efficiently applied to a pulley of small diameter, and it is only suitable for the measurement of a motor of small power.

A Friction-Brake of a convenient and efficient form for testing the power of an engine is shown in Fig. 2. It consists of a strap of hoop-iron lined with blocks of wood, placed round a pulley or fly-wheel on the crank-shaft of the engine. A weight is hung on one end of the strap, and the other end is connected to a spring-balance, or a small weight may be used instead of a spring-balance. The end of the strap carrying the ascending weight should be confined by a loose cord to prevent it being carried over the pulley.

Belt - Friction - Brake.—A friction-brake of simple, but reliable, description and easy of application is shown in Fig. 3. It consists simply of a leather - belt hung over the driving-pulley or fly-wheel of the engine, having a weight attached to the ascending end, and a spring-balance at the other end. The weight is prevented from being carried over the pulley while the engine is working by a safety-stop, consisting of a number of narrow strips of half-round iron riveted on the inside of the ascending end of the belt. These strips come in contact with the face of the pulley, diminish the friction, and stop the ascent of the weight, in case it ascends much higher than its normal position when the brake is fully loaded. The engine lifts the weight, and the effective weight lifted is equal to the weight on the ascending end of the belt, minus the weight indicated by the spring-balance on the descending end. The effective weight multiplied by the circumferential velocity of the pulley in feet per minute, and divided by 33,000 gives the brake-horse-power of the engine.

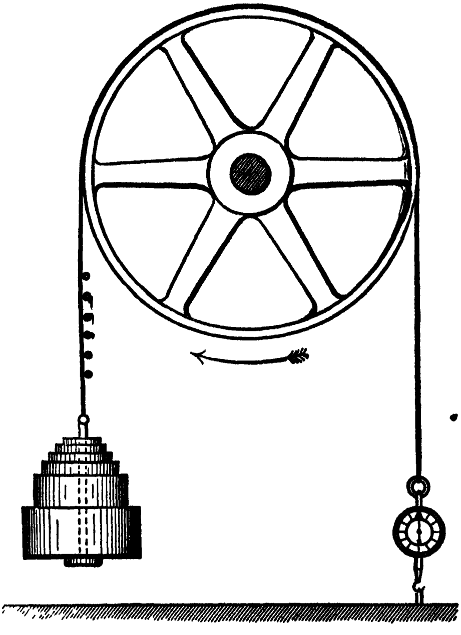


Fig. 3.—Leather-Belt-Friction-Brake.

Example.—Required the power of an engine which, when tested by a belt-friction-brake, lifted a weight of 168 lbs. suspended from a belt placed over a pulley 3 feet 6 inches diameter, making 100 revolutions per minute; the weight indicated by the spring-balance being 18 lbs.

$$\text{Then } \frac{(168-18 \text{ lbs.})\times(3.5 \text{ feet} \times 3.1416 \times 100 \text{ revolutions})}{33{,}000}=5,$$

the brake horse-power of that engine.

To prevent the belt slipping off the pulley several light clips may be riveted on the outside of the belt, formed with ends projecting over the sides of the pulley.

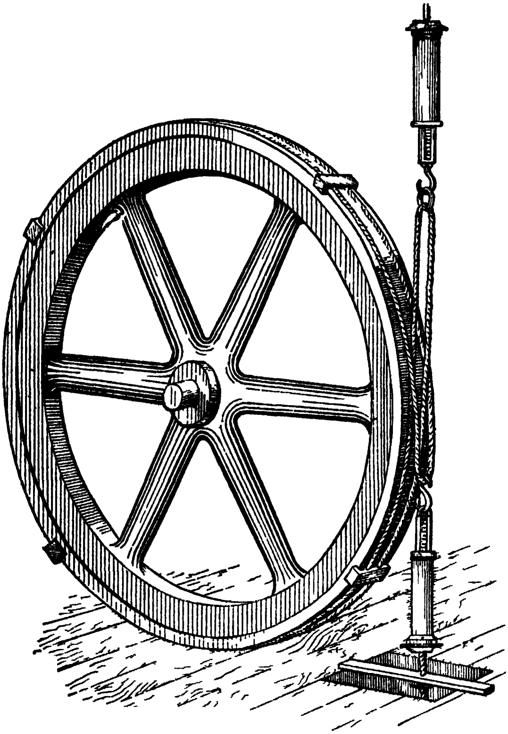


Fig. 4.—Rope Friction Brake.

Rope-Friction-Brake.—A simple and efficient form of friction-brake was used in some tests of a 6 horse-power horizontal gas engine. It consisted of an endless rope or sling-rope, placed round the fly-wheel of the engine, having each end of the sling attached to a spring-balance as shown in Fig. 4. A weight may be used in place of the bottom spring-balance, but it is not so convenient to adjust. The rope is kept in its place by clips.

Size of Friction-Brake.—In determining the most efficient size of friction-brake to be employed for the absorption of a given horse-power at a given speed, it has been found that the result of the speed of the circumference of the pulley in feet per minute, multiplied by the width of its face in inches and divided by the horse power, should not be less than 750.

THE INDICATOR.

The Indicator.—The action of steam in a cylinder can only be correctly ascertained by means of an indicator. It shows the pressure of the steam at each point of the stroke, the power and performance of the engine, the amount of back pressure or force opposed to the motion of the piston, and enables any imperfections to be detected in the construction of the valve, steam-ports, and steam-passages. Two of the best known indicators are the "Crosby" and the "Dobbie McInnes."

Indicator Diagrams.—Supposing the indicator to be fixed to a cylinder, and that the drum is connected by means of a cord to some part of the engine, which has a motion co-incident with that of the piston, if the barrel be allowed to rotate before the indicator-cock is opened, a horizontal line is traced, which is called the atmospheric line, and all portions of the diagram above that line, represent steam-pressures, and all portions below that line represent vacuum.

If the indicator-cock be opened at the beginning of the stroke, when steam enters the engine-cylinder, the pencil moves upwards and traces a vertical line, and as the piston moves forward the indicator barrel rotates and a horizontal line is traced until the steam is cut off; then, as the expanding steam increases in volume, it declines in pressure, which causes the pencil to gradually fall and describe a curved line until the exhaust-port is opened, when the pencil immediately falls and describes the "toe" of the diagram. On the return-stroke the pencil traces the bottom or exhaust-line of the diagram until the closing of the exhaust-port, when cushioning commences, then the pressure rises and moves the pencil up and completes the diagram.

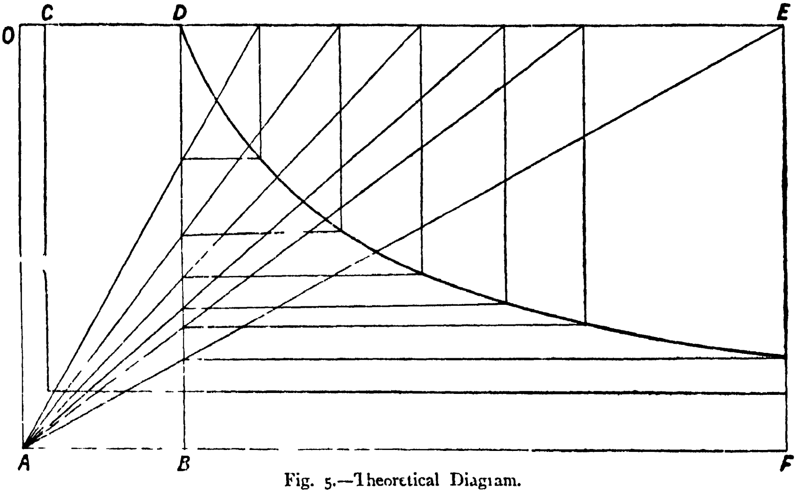


Fig. 5.—Theoretical Diagram.

Theoretical Indicator-Diagram.—The rules for the expansion of steam are based upon the approximately correct law of gases, viz., that the pressure of gas varies inversely as the volume, or the product of the pressure and volume of a gas is always a constant, other conditions being unaltered; and in order to ascertain the varying pressure and volume of steam during expansion, it is necessary to construct a theoretical diagram according to this law, the descending curve of which represents the decreasing force of the steam as it expands in volume. This curve is called a hyperbolic curve, and is the standard by which the character of all expansion curves in indicator-diagrams is determined. To draw the theoretical curve upon a diagram as shown in Fig. 5, draw the line A F, representing the line of perfect vacuum, parallel with the atmospheric line, and at the proper distance below it to represent 14·7 lbs.; and perpendicular to the line A F draw A O, representing the clearance space; draw the line C D, representing the period of admission of the steam; from the point D draw the vertical line D B; draw the line D E; from A to F represents the full length of stroke; divide the distance D E into a number of parts, from which points draw diagonal lines to the point A; from the points where the diagonal lines cut the vertical line D B, drawn horizontal lines; and the points where the vertical lines drawn from the points in the line D E meet these horizontal lines, will be the points of the hyperbolic curve, which may be drawn in by hand.

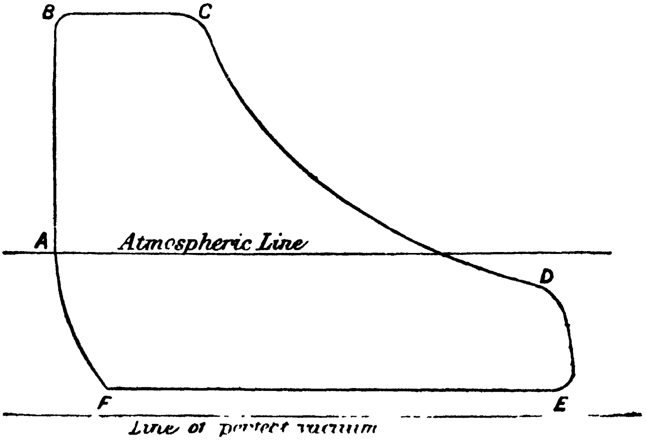


Fig. 6. - Indicator-Diagram.

Indicator-Diagrams, Fig. 6.– The lines forming the outline of a diagram during one revolution of the engine are as follows:—

A to B, The admission-line.
B to C, The steam-line.
C to D, The expansion-curve.
D to E, The exhaust-line.
E to F, The line of back-pressure.
F to A, The compression-line.

In Fig 6, A is the point of pre-admission, the steam having been admitted a little before the beginning of the steam-stroke, due to the lead of the valve, to ensure having the full pressure of steam in the cylinder at the beginning of the stroke.

Admission-Line, Fig. 6.—A to B is the admission-line. This line is formed by the rise of pressure in the cylinder as the port is opened for the admission of steam; the full pressure of the steam should come on to the piston at the beginning of the stroke, and the admission corner should be sharp. When it is rounded as at A in Fig. 7, or when it slants, as at B, it shows that the steam is admitted too late and the momentum of the piston at the commencement of the stroke is imparted by the engine. To remedy this, the valve requires more lead. When the valve has excessive lead, and steam enters too soon, it will produce a slanting line like C, Fig. 8; to remedy this the valve requires less lead.

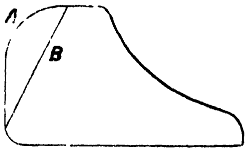


Fig. 7.—Diagram.

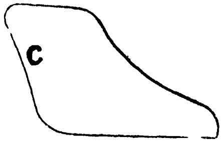


Fig. 8.—Diagram.

Steam-Line.—B to C, Fig. 6, is the steam line or period of admission of the steam. This line is formed by the advance of the piston while the port remains open for the admission of steam; the full pressure of steam should be maintained in the cylinder during the whole period of admission, and the steam line should be straight and horizontal, or parallel with the atmospheric line up to the point of cut off; when this line falls, like D in Fig. 9, the fall is due either to condensation in the cylinder, or to the ports and steam pipes being too small, which wiredraws and reduces the pressure of the steam.

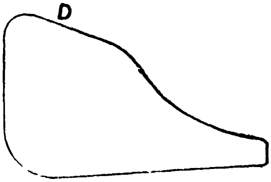


Fig. 9.—Diagram.

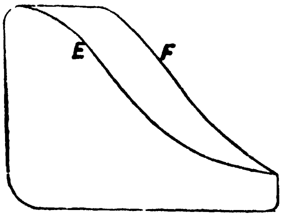


Fig. 10.—Diagram.

The Point of Cut-Off, Fig. 6.—C is the point of cut off or suppression. As expansion does not properly commence until the port is closed, the action of the valve in cutting off the steam should be sharp and sudden, and the pressure should fall as little as possible during the closing of the port. The point of cut off should be sharp and clear. When this corner is rounded, like E in Fig. 10, it shows that the valve does not close quickly enough, and that the expansion arrangements are defective. When the steam is cut off slowly it causes a fall of pressure in the cylinder before the port is completely closed. When this corner shows a gradually descending line like F in Fig. 10, it shows that some steam has entered the cylinder after it was supposed to have been cut off.

The Expansion-Curve.—C to D, Fig. 6, is the expansion curve or period of expansion. In a condensing-engine this curve is partly above and partly below the atmospheric-line, but in a non-condensing engine the whole of the curve is above the atmospheric-line. This curve should approach as nearly as possible in form to that of the theoretical diagram, unless it be filled up by leaky valves, or diminished by steam leaking past the piston. When the cylinder is not properly protected, there will be great loss of heat from radiation, and fall of pressure during expansion, which will cause the expansion curve to fall below the theoretical curve. When the curve rises above the theoretical curve, it is generally due to a leaky valve, owing either to the valve being defective in rigidity, which causes it to bend into the ports in passing over them, or to the valve being deficient in wearing surface. When the expansion curve rises above the theoretical curve towards the end of the stroke, it shows that the steam has been condensed at the beginning of the stroke, and evaporated by the walls of the cylinder towards the end of the stroke.

Point of Pre-release.—D, Fig. 6, is the point of exhaust or pre-release, the exhaust-port being opened before the end of the stroke. The pre-release should allow all the steam in the cylinder to escape before the piston arrives at the end of the stroke, so that during the return-stroke the back-pressure may be as low as possible.

Exhaust-Line.—D to E, Fig. 6, is the exhaust-line. The full expansive force of the steam during the steam-stroke, should be employed as nearly as possible to the end of the stroke, and then the steam should be discharged as rapidly as possible, so as not to hinder the return of the piston. When the exhaust-pipe and exhaust-passages are cramped, or when the exhaust is too late, all the steam cannot escape properly before the end of the return-stroke, which will cause a bad exhaust-line, and the expansion-curve will be continued to the end of the diagram. The exhaust-line will be shown slanting gradually downwards, as at G, Fig. 11, as the piston advances on its return stroke, instead of being horizontal. When the exhaust is too soon, the exhaust-line will slope down, as shown at H, Fig. 12.

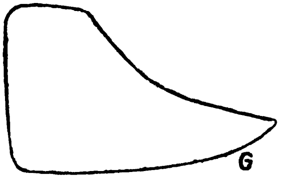


Fig. 11.—Diagram.

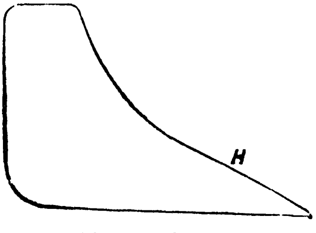


Fig. 12.—Diagram.

Line of Back-Pressure.—E to F in Fig. 6 is the line of back-pressure, or period of exhaust, during the return-stroke. This line extends from the beginning of the return-stroke to the point at which the exhaust-port is closed. In a condensing-engine the steam-pressure will fall below the atmospheric-line, but in a non-condensing engine the pressure cannot fall to the atmospheric line, because there is always an amount of back-pressure, due to the force required to expel the exhaust-steam through the exhaust-passages and pipe against the resistance of the atmosphere. In a condensing-engine, the deeper the line of back-pressure measures from, and the more nearly parallel it is to, the atmospheric-line, the better. In a non-condensing engine, the nearer and more parallel the line of back-pressure is to the atmospheric-line the better, as back-pressure not only means a loss of force, but it diminishes the efficiency of the engine.

Point of Compression.—F, Fig. 6, is the point of compression. This line is formed by the closing of the exhaust-port at some point before the end of the return-stroke. The advancing piston compresses the confined steam into the clearance-space and passages, and provides a cushion which absorbs the momentum of the piston, and enables its motion to be reversed without shock. The rise of pressure is shown by the rising curve at F, and the portion of the stroke between F and A is the period of compression or cushioning. Excessive compression causes the confined steam to rise above its initial pressure before pre-admission commences, as shown by the loop at the admission-corner in Fig. 13, consequently, when the port is opened, part of the confined steam flows from the cylinder into the steam chest, and the pressure is reduced and the steam line is lowered, as shown in Fig. 13. In slow running engines only a small amount of cushioning is necessary, but in high-speed engines the cushioning should be so adjusted that the confined steam is compressed up to its initial pressure. The compressed steam acts as an elastic spring, and gives out by its expansion the work expended in compressing it. The effect of compression is to fill the clearance-space with compressed steam, and save steam being taken from the boiler for that purpose.

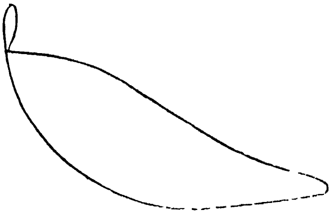


Fig. 13.—Diagram.

The Line of Perfect Vacuum.—This line cannot be drawn by the indicator; it must be drawn by hand, parallel with the atmospheric line, and at the proper distance below it to represent, say, 14·7 lbs. per square inch, as the average pressure of the atmosphere, according to the scale of the diagram. In measuring the diagram of a condensing-engine, the distance between the vacuum-line of the diagram and the line of perfect vacuum, will show the quantity of uncondensed steam in the cylinder or the amount of back-pressure due to imperfect vacuum, slightly varying according to the barometric pressure. The temperature of the condensed water is usually about 100° F., or about 1 lb. pressure per square inch, but the pressure of air in the condenser prevents the pressure from falling below 2 lbs. per square inch. The usual final-pressure is at least from 4 to 5 lbs. per square inch.

The initial-pressure of steam in a cylinder is always 4 or 5 lbs. less than the boiler-pressure; but when the fall of pressure is much more than this, it is due either to bends in the steam-pipes, or to the steam-pipes being too small, or to the steam-ports being too contracted.

To find the indicated horse-power of an engine from an indicator-diagram. Divide the diagram at right angles to the atmospheric-line into 10 equal parts, take the breadth in the middle between the divisions with the scale of the indicator, add them together, and divide by 10 (the number of divisions)—the result will be the mean or average pressure per square inch on the piston during the stroke; then multiply the area of the cylinder in square inches by the mean-pressure, and by the speed of the piston in feet per minute. The product divided by 33,000 gives the indicated horse-power of the engine.

The speed of the piston in feet per minute is found thus:—Multiply the length of stroke in feet by 2, and by the number of revolutions per minute. A deduction of 2 lbs. per square inch, from the gross diagram must be made for the friction of the engine alone; but if the diagram is taken when the load is on the engine, an additional deduction must be made of 5 per cent. for friction.

A constant may be found for any particular engine, which, being multiplied by the mean-pressure, will give the horse-power. To find the constant multiplier: multiply the area of the cylinder in square inches, by the speed of the piston in feet per minute, and divide the product by 33,000. The quotient will give the number of horse-power which would be produced by 1 lb. of steam of mean-pressure.

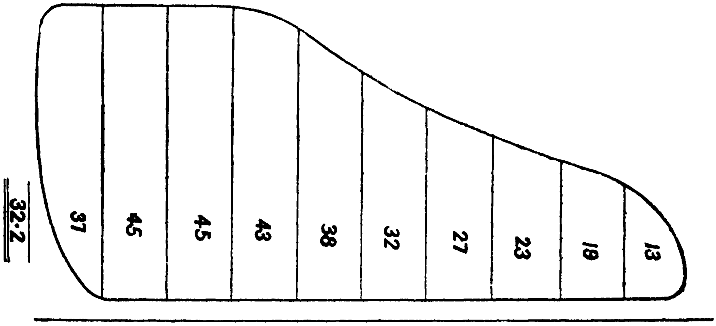


Fig. 14.- Indicator Diagram.

Example.—Required the power of the engine from which diagram, Fig. 14, was taken. Diameter of cylinder, 12 inches; length of stroke, 2 feet; number of revolutions, 80 per minute. The mean pressure according to the diagram is 32·2 lbs., from which deduct 2 lbs. for the friction of the engine, leaving 30·2 lbs. pressure; the area of the cylinder is 113 inches; then $\frac{113 \times 30{\cdot}2 \times 2 \times 2 \times 80}{33{,}000} = 33$, indicated horse-power

STEAM-PRESSURE.

Pressure of Steam.—The pressure of steam is equal in all directions, therefore each square inch of surface exposed to its action must be equally capable of bearing the given pressure. The pressure is measured from that of the atmosphere, or 14·7 lbs. per square inch.

Effective-Pressure.—In a non-condensing engine the pressure of the steam is opposed by that of the atmosphere, therefore only pressures above that of the atmosphere are effective for work, and a deduction must also be made for the resistance due to back-pressure, caused by the resistance of the exhaust-passages, which may be reckoned at 2 lbs. per square inch. In a condensing-engine the pressure of the steam is only opposed by a back pressure of from 2 to 3 lbs. per square inch, due to imperfect vacuum.

The initial-pressure of steam is its pressure when admitted to the cylinder.

The final-pressure of steam is its pressure when discharged from the cylinder.

The mean-pressure is the average pressure upon the piston through the whole stroke.

The effective mean-pressure is the mean-pressure less the back-pressure.

The ratio of expansion is the proportion which the final volume bears to the initial volume of steam.

The relative volume of steam is the volume of steam generated from a given volume of water divided by this volume.

The absolute-pressure of steam is the pressure of steam given by the steam-gauge plus the pressure of the atmosphere.

To find the quantity of steam used by an engine, multiply the area of the cylinder in square feet by the speed of the piston in feet per minute, and divide the result by the nominal ratio of expansion. The result will be the number of cubic feet of boiler-pressure-steam consumed per minute, to which 10 per cent. must be added for the clearance of the cylinder and capacity of the steam-passages.

To find the pressure in lbs. per square inch of the steam at any point of the period of expansion, multiply the initial-pressure by the distance moved by the piston when the steam is cut off, and divide the product by the distance of the given point from the beginning of the stroke.

To find the point to cut off the steam for a given actual ratio of expansion, add the clearance to the length of stroke and divide by the ratio of expansion; from the quotient deduct the clearance, and the remainder will be the point of the stroke at which to cut off the steam.

Steam-Table.—The temperature, weight, and relative volume of steam for various pressures are given in the following table:

Table I.—Properties of Saturated Steam.

IN FOOT—POUND—FAHRENHEIT UNITS.

Absolute Pressure. lbs. per sq. in.	Temperature, Deg. F.	Heat in Mean B. Th. Us. per lb.			Specific Volume, cu. ft. per lb.
		Sensible Heat. *h*.	Latent Heat. *L*.	Total Heat. H_s.	
p.	*t*.				V_s.
14·69	212·0	180·0	970·7	1150·7	26·79
20	228·0	196·1	961·0	1157·1	20·08
25	240·1	208·4	953·3	1161·7	16·29
30	250·3	218·8	946·8	1165·6	13·74
35	259·2	227·9	940·9	1168·8	11·90
40	267·2	235·9	935·8	1171·7	10·50
45	273·5	242·0	931·2	1173·2	9·39
50	280·9	250·0	926·5	1176·5	8·52
55	286·3	256·2	922·5	1178·7	7·85
60	292·6	262·0	918·4	1180·4	7·18
65	297·0	266·4	914·8	1181·2	6·70
70	302·8	272·5	911·2	1183·7	6·22
75	307·2	277·2	908·0	1185·2	6·03
80	311·9	281·9	904·7	1186·6	5·85
85	316·2	286·2	901·7	1187·9	5·38
90	320·2	290·4	898·7	1189·1	4·91
95	323·9	294·5	895·3	1189·8	4·68
100	327·7	298·3	893·0	1191·3	4·45
110	334·7	305·6	887·7	1193·3	4·07
120	341·1	312·3	882·8	1195·1	3·75
130	347·2	318·7	878·0	1196·7	3·48
140	353·0	324·8	873·4	1198·2	3·25
150	358·4	330·5	869·2	1199·7	3·04
160	363·5	335·9	865·1	1201·0	2·86
170	368·4	341·1	861·1	1202·2	2·70
180	373·0	346·1	857·3	1203·4	2·56
190	377·5	350·9	853·5	1204·4	2·44
200	381·8	355·5	849·9	1205·4	2·32
210	386·0	359·9	846·5	1206·4	2·22
220	390·0	364·2	843·1	1207·3	2·12

Table I (*continued*).—PROPERTIES OF SATURATED STEAM.

IN FOOT—POUND—FAHRENHEIT UNITS.

Absolute Pressure. lbs. per sq. in.	Temperature, Deg. F.	Heat in Mean B. Th. Us. per lb.			Specific Volume. cu. ft. per lb.
		Sensible Heat.	Latent Heat.	Total Heat.	
p.	*t*.	*h*.	*L*.	H_s.	V_s.
230	393·8	368·4	839·7	1208·1	2·03
240	397·6	372·4	836·6	1209·0	1·95
250	401·2	376·3	833·4	1209·7	1·88
260	404·7	380·1	830·4	1210·5	1·81
280	411·4	387·4	824·4	1211·8	1·69
300	417·8	394·4	818·7	1213·1	1·58
320	423·8	401·1	813·2	1214·3	1·49
340	429·6	407·4	808·0	1215·4	1·41
360	435·1	413·6	802·8	1216·4	1·33
380	440·4	419·5	797·9	1217·4	1·27
400	445·5	425·2	793·1	1218·3	1·21
420	450·5	430·7	788·4	1219·1	1·15
440	455·2	436·0	784·0	1220·0	1·10
460	459·8	441·2	779·5	1220·7	1·06
480	464·3	446·3	775·1	1221·4	1·02
500	468·6	451·2	771·0	1222·2	0·98
525	474·2	457·0	766·0	1223·0	0·94
550	478·9	463·0	760·8	1223·8	0·89
575	483·1	467·5	752·5	1220·0	0·84
600	485·4	471·6	740·4	1212·0	0·78

Steam worked Expansively.—Steam, in its ordinary condition as saturated steam, although it is not a perfect gas, performs work in the cylinder of an engine practically the same as if it acted on the principle of a perfect gas. Hence the curve described by the pencil of an indicator, indicating the falling pressure of dry saturated steam expanding behind an advancing piston, is nearly hyperbolic in its nature, or such that the products of the pressures at all points of the stroke, multiplied by the respective volumes of the steam, are equal to each other.

The work performed by steam expanded in a cylinder may be calculated by means of Hyperbolic Logarithms given in the following Table.

Table 2.—HYPERBOLIC LOGARITHMS.

Number.	Logarithm.	Number.	Logarithm.	Number.	Logarithm.
1¼	·2231	5½	1·7047	9¾	2·2773
1½	·4054	5¾	1·7492	10	2·3026
1¾	·5596	6	1·7918	10¼	2·3279
2	·6931	6¼	1·8325	10½	2·3513
2¼	·8109	6½	1·8718	10¾	2·3749
2½	·9162	6¾	1·9095	11	2·3979
2¾	1·0116	7	1·9459	11¼	2·4201
3	1·0986	7¼	1·9810	11½	2·4430
3¼	1·1787	7½	2·0149	11¾	2·4636
3½	1·2528	7¾	2·0477	12	2·4849
3¾	1·3217	8	2·0794	12½	2·5262
4	1·3862	8¼	2·1102	13	2·5649
4¼	1·4469	8½	2·1401	14	2·6391
4½	1·5040	8¾	2·1691	15	2·7081
4¾	1·5581	9	2·1972	16	2·7726
5	1·6094	9¼	2·2246	17	2·8332
5¼	1·6582	9½	2·2513	18	2·8904

The temperature of expanding steam at any instant is the same as that which accompanies the pressure at that instant, according to Table 1.

Expansive-Work of Steam in a Cylinder.—If there were no clearance in a cylinder, and the total work performed by the steam during its admission be represented by 1, the additional work performed by expanding the steam to the end of the stroke, is represented by the hyperbolic logarithm of the ratio of expansion. The ratio of expansion is, if there be no clearance, expressed by the quotient obtained by dividing the length of stroke by the period of admission. Adding the work done during admission and that done during expansion together, the whole work done in one stroke is represented proportionally by—

$$1 + \text{Hyperbolic Logarithm of ratio of Expansion.}$$

This expression shows the whole work done during admission to the cylinder, as well as during expansion for the remainder of the stroke, supposing the work done in admission is represented by 1. And, to find the total actual work done in any case, this expression must be multiplied by the actual work during admission. For instance, take a cylinder 12 inches diameter with 2 feet stroke, without clearance, having steam of 60 pounds pressure above the atmosphere admitted on the piston during 6 inches, or one-fourth of the stroke. Then the area of the piston is $= 12 \times 12 \times {}\cdot7854 = 113\cdot1$ square inches; and the whole pressure on the piston is $113\cdot1 \times 60$ lbs $= 678\cdot6$ pounds. The product of the whole pressure by the length in feet of that portion of the stroke during which steam is admitted, expresses the total work during admission, in foot-pounds = 678·6 pounds × ·5 foot = 339·3 foot-pounds. The ratio of expansion is 2 ÷ 5 = 4, that is, the steam is expanded four times. The Hyperbolic Logarithm of 4 is, from Table 2 = 1·3862, and 1 + 1·3862 = 2·3862, and 339·3 foot-pounds × 2·3862 = 809·637 foot-pounds the total work of the stroke, effected by the admission initially for the fourth of the stroke, showing that the work performed by the steam initially has been increased to more than $2\frac{1}{3}$ times its amount, by the simple act of expansion after the steam from the boiler ceased to flow into the cylinder.

CYLINDERS OF STEAM-ENGINES.

Condensation.—It is found in practice that simple steam engines use half as much more steam than is theoretically required, and this loss is mostly caused by condensation of the steam in the cylinder. When steam enters a cold cylinder, it is rapidly condensed during the operation of warming the cylinder and piston, and raising their heat up to the same temperature as the steam, because the piston will not move until both it and the surrounding surfaces are heated to a temperature approaching more or less that of the steam. Re-evaporation takes place during the whole time of exhaust. The steam, when exhausting after expansion, being lower in pressure and temperature, cools the cylinder and steam passages, and absorbs the heat. The heat thus abstracted must be restored to the metal by the entering steam, a portion of which must be condensed to restore the heat thus lost, because, as already stated, until the metal is considerably raised in temperature, the heat in the entering steam will be expended in heating the surfaces, instead of moving the piston. Condensation also goes on in the cylinder, due to the performance of work during expansion in driving the piston. The steam falls in temperature owing to its change in volume during expansion, and the temperature of the interior surfaces of the cylinder also falls during expansion, nearly with that of the steam, parting with heat to re-evaporate the water formed. Therefore, at the commencement of each stroke, a portion of the entering steam must be condensed to restore the heat lost by condensation and the cooling of the cylinder by re-evaporation during the previous expansion, as well as the heat abstracted by the steam during exhaust.

The extent to which cylinder condensation takes place depends upon the extent of the cooling surfaces opposed, and also upon the quantity of water mixed with the steam and carried with it from the boiler; but part of the water formed from the condensed steam is re-converted into steam during expansion, and the heat necessary for its re-evaporation is supplied from three sources. First, from the heat stored in the metal which was abstracted from the entering steam. Secondly, from the sensible heat given up by the steam as it falls in pressure and temperature during expansion. Thirdly, from the latent heat given up by the steam during condensation. So that the action of condensation and re-evaporation is continually going on in the cylinder. Condensation varies as the size of cylinder, for as the diameter is increased, the condensing surfaces increase directly as the diameter; but the area and consequently the volume of steam increases as the square of the diameter; the condensing surfaces of the piston and cylinder-ends increase as the square of the diameter; but the volume of steam cut off at a given proportion of the stroke increases directly as the length of stroke, so that the loss from condensation diminishes as the diameter of cylinder and the length of stroke are increased. Condensation also varies with the rate of expansion; the weight of steam condensed increases rapidly with each increase in the ratio of expansion.

Cylinder-Condensation causes a great loss of both steam and fuel, and forms an obstacle to working expansively; in fact, unless the cylinder is protected in some way, so as to keep up the temperature of the steam during expansion the full benefit cannot be derived from working expansively. If steam could only be maintained at a suitably high temperature during expansion, without condensation, then the reduction of pressure during expansion would be the exact equivalent of the work done in expanding. It is found in practice that even in cylinders jacketed in the best manner the loss from condensation is at least from 1½ to 2 lbs. per horse-power per hour, and in unjacketed but well clothed cylinders the loss from condensation is from 4½ to 5 lbs. per horse-power per hour.

Leaky Pistons are another source of loss, and the amount of steam which from this cause escapes past the piston increases with the pressure of the steam and also with the age of the engine, so that a quantity of steam is continually passing through the cylinder without performing any work.

Leaky Valves also cause loss by admitting the steam after it is supposed to be cut off, and the initial work of such steam is lost, the cause of leakage being either want of stiffness in the valve, which allows it to bend into the ports in passing over them, or the surface is made so small that capillary attraction does not properly take place between the valve and its seat.

Clearance between the piston and the cylinder-covers, and the space occupied by the steam-passages, cause considerable loss, because these spaces are emptied of steam at each exhaust, and have to be re-filled at the beginning of each stroke, and the steam thus used does no work during admission, although it is not altogether lost, because it acts by expansion during the stroke.

Compression.—The loss due to clearance and waste-room in the steam passages may be avoided by compressing the steam; this is accomplished by closing the exhaust-port a little before the termination of the return stroke, and the advancing piston compresses the confined steam against the cylinder-end. This is motion against resistance, and the work lost by the piston is imparted as heat to the steam, the compression of which raises its temperature, and its pressure can thus be raised up to its initial pressure, and heat will be applied to the cylinder-covers and piston, which would otherwise be abstracted from the steam from the boiler, and condensation is prevented to that extent.

Cushioning.—Another great advantage from compression is that the compressed steam acts as a cushion to the piston, and prevents a sudden shock at the end and beginning of each stroke, when the motion of the piston is reversed, and the power used in compressing the steam (with the exception of loss from friction) is returned by the re-expansion of the compressed steam on the reversal of the piston. By properly adjusting the *quantity of cushion*, the momentum of the piston may be balanced, and the engine may be made to run smoothly and noiselessly.

Back-Pressure causes loss of power, the extent of which depends upon the quantity of water mixed with the exhaust-steam, and also upon the amount of resistance opposed to the escape of the exhaust-steam from the cylinder, in the shape of contracted ports and passages and bent exhaust pipes. Bends and elbows in the exhaust-pipe cause great back-pressure, but in non-condensing engines the back-pressure is never less than the pressure of the atmosphere, plus the power required to expel the exhaust steam from the cylinder. In condensing-engines, the condenser and air-pump are employed to remove the back-pressure or pressure of the atmosphere, but as a perfect vacuum is never obtained and there is always some resistance to the escape of the steam from the cylinder, there is always a back-pressure of at least 2 lbs. per square inch in condensing-engines.

Ratio of Expansion.—In order to obtain all the available power, the steam should be brought on to the piston at its highest pressure and cut off quickly, so that the pressure does not fall during the closing of the port, as expansion cannot begin properly until the port is closed, and the full expansive force of the steam should be used as nearly as possible to the end of the stroke, and then exhausted freely, therefore the steam must be cut off at such a part of the stroke that it will expand to the lowest practicable point. In practice with saturated steam the best results have been obtained by expanding the steam 6 times in single-cylinder steam-jacketed condensing-engines; 4 times in single-cylinder condensing-engines without steam jackets; 3½ times in single-cylinder steam-jacketed non-condensing engines; 3 times in single cylinder non-condensing engines without steam jackets, but with well-clothed cylinders; 8 times in double-expansion condensing steam-jacketed engines; 6 times in double-expansion condensing engines without jackets, but with well-clothed cylinders; 10 times in triple-expansion surface-condensing engines: and 12 times in quadruple expansion surface-condensing engines. In all cases the utmost feasible ratio of expansion is the number of times the total back pressure is contained in the total initial pressure.

Lowest Absolute Terminal-Pressure.—In non-condensing engines, the exhaust port being open to the atmosphere, there is a back pressure of

15 lbs. per square inch, plus the power necessary to drive the engine against its own friction, and to expel the exhaust steam from the cylinder, which is on an average 5 lbs.; so that the lowest terminal absolute pressure to which steam can be economically expanded is 20 lbs. In condensing engines, there is always a pressure in the condenser to be provided against, as well as the resistance to the escape of the steam from the cylinder, and the power necessary to drive the engine against its own friction, so that the lowest terminal absolute pressure to which steam can be economically expanded, is 8 lbs. per square inch. When the steam is expanded to a lower terminal pressure than this, the result will be loss of power.

Economical Working.—To secure the utmost economy, it is necessary to work at a good rate of expansion with dry steam, and this can only be obtained by keeping the steam in the cylinder at such a point, that it will be as nearly as possible totally free from condensation; for this purpose the steam jacket was designed.

Steam-Jackets.—The object of the steam-jacket is to maintain a uniform temperature in the cylinder, and obtain dry steam throughout the stroke, by preventing condensation in the cylinder. The effect of the jacket is to remove the condensation from the inside of the cylinder, where it retards the effective working of the piston, to the outside of the cylinder into the jacket, whence it can easily be drained off and returned to the boiler as feed-water. To enable the jacket to work properly, means must be provided to keep it clear of both air and water, otherwise they will destroy its action. It is essential to supply the jacket with dry steam, of a temperature not less than that of the steam on entering the cylinder, and the jacket should be drained automatically by a steam-trap. Exhaust-steam should not be used for heating the jacket, as the cylinder would be enveloped in steam of a less temperature than that inside the cylinder, and the heat would flow from the hotter to the colder steam and cause loss of power.

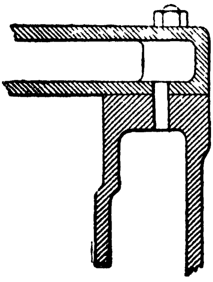


Fig. 15.—Steam-Jacket.

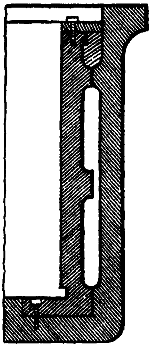


Fig. 16.—Steam-Jacket.

A simple form of steam-jacket, cast in one piece with the cylinder, as shown in Fig. 15; the cylinder covers are also jacketed. The jackets of the cylinder and cover should be connected by at least 6 holes, and care must be used in making the joint to prevent these holes from being filled up with red lead, but pieces of tube screwed into the cylinder-cover effectually prevents this taking place. The jacket is filled with steam from the boiler, and condensation in the cylinder during expansion is prevented by the heat passing from the jacket to the expanding steam.

Another method of jacketing a cylinder is shown in Fig. 16. It is formed by fitting a liner of either hard close-grained cast-iron, or compressed steel, in the cylinder. The liner has a flange at one end, by which it is bolted to the cylinder, the other end of the liner is not fixed to the cylinder, but is free, to allow it to expand, and it is fitted in some cases with a plate, covering a recess filled with packing, to prevent leakage of steam.

Numerous experiments have been made to determine the economical value of steam-jackets. The results of several tests are as follows:—

			Economy effected by using a Steam-Jacket. Per cent.
Simple non-condensing-engine of	10	indicated horse power	32
„ „	14	„ „	30
„ „	20	„ „	28
„ „	28	„ „	26
Single cylinder condensing-engine	62	„ „	23
„ „	101	„ „	22
Compound, or double-expansion condensing-engine	76	„ „	34
„ „	112	„ „	26
„ „	173	„ „	24
„ „	304	„ „	16
„ „	517	„ „	14
Corless-engine	155	„ „	19

The economy effected by steam-jacketing a cylinder depends partly upon the rate of expansion. The higher the rate of expansion in a single cylinder the greater is the advantage derived from the use of a steam-jacket, because the higher the rate of expansion the greater the variation of temperature of steam in the cylinder. In one case the saving effected by the use of a steam-jacket was 27 per cent. when the steam was expanded 6 times and 15 per cent. when the steam was expanded 2½ times in the cylinder. The steam jacket is most effective when applied slow-speed engines with high ratio of expansion ; and to low pressure cylinders of multiple cylinder engines. High steam pressures and temperatures are more economical than jacketing.

MOVEMENT OF THE PISTON AND SLIDE-VALVE OF A STEAM-ENGINE.

Movement of the Piston relative to that of the Crank.—The piston acts upon the crank through the medium of the connecting-rod. The piston traverses twice the diameter of the path-circle of the crank-pin while the crank-pin describes the circumference, during one revolution of the crank. The varying angularity of the connecting-rod influences the movement of the piston in such a manner that, the piston moves more slowly during one half of its stroke than during the other.

With an indefinitely long connecting-rod, of which the angularity is inconsiderable, the relation of the motion of the crank and the piston is shown in Fig. 17, in which A C is the stroke of the piston, and A B C the half-revolution of the crank-pin, simultaneously described. Let the path of the crank-pin be divided into equal parts at the points 1, 2, 3, 4, and draw vertical lines from the points of division to the line A C. Then, as the angular speed of the crank-pin is uniform and the divisions of the circular path A B C are equal, the line A C is divided by the perpendiculars into segments representing spaces described by the piston in equal times, and therefore also the varying average velocity of the piston in traversing these spaces. Showing that, the speed of the piston, during one stroke, begins and ends at nothing at the extreme or dead-points, A C; and it accelerates towards B, the position at half-stroke, where it reaches a maximum, and that beyond this point it is retarded until it gains the end of its stroke. The piston moves at the same rate as the crank-pin only for a brief period about the middle of the stroke. The piston is stopped twice and started twice in each revolution of the crank. The stoppage of the piston at the end of each stroke permits an element of time for the steam to get in and out of the cylinder.

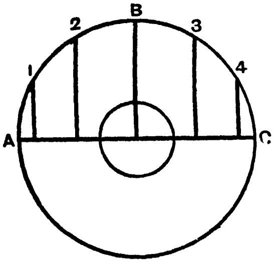


Fig. 17.—Diagram of Piston-Movement.

Movement of the Slide-Valve.—The small circle in Fig. 17 shows the path of the centre of the eccentric, in which the travel of the valve is represented by the diametrical line. The slide-valve travels in a similar manner to the piston. The slide-valve opens the ports for the admission of steam to the cylinder towards the middle of its travel, when its velocity is greatest and its action quickest.

Slide-Valves.—The admission, expansion and exhaust of steam in the cylinder is regulated by the slide-valve, a simple form of which is shown in Fig. 18. The slide-valve should give sufficiently early admission, or pre-admission, of the steam to the cylinder to enable the piston to commence its stroke with the full pressure of the steam behind it; and the valve should cut the steam off quickly to prevent wiredrawing; and it should effect the release of the steam from one side of the piston, and its compression on the other without causing unavoidable back-pressure.

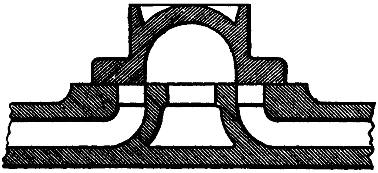


Fig. 18.—Slide Valve.

Lead of a valve is the distance that the port is open at the commencement of the stroke of the piston, for the purpose of obtaining the full pressure of the steam on the piston when it leaves the end of the cylinder at the commencement of its stroke. This is effected by fixing the eccentric a little in advance of the position at right angles to the crank, which causes the port to be slightly open before the piston arrives at the end of its stroke, so that the moment the crank has passed its dead-centre the piston begins its stroke with the full pressure of the steam behind it. The amount of lead depends upon the speed of the piston, the size of the ports, the quantity of steam in the cylinder at the time the valve is opened. The valves of vertical engines are generally given more lead at the bottom than at the top, to balance the momentum of the moving parts as they reach the bottom-centre.

Insufficient lead causes the piston to travel a portion of its stroke before it receives the full pressure of the steam: and excessive lead causes an irregular working of the piston, which receives a sudden shock, and the entering steam is compressed, which causes back pressure and loss of power, besides straining the engine.

Lap of a Valve.—In order to work expansively, the admission of the steam is cut off and the steam is confined in the cylinder, when the piston has only travelled a portion of its stroke, and this is effected with the common slide-valve by making it sufficiently long, when in middle position, to overlap the extreme edges of the steam-ports. The overlap is called outside-lap.

Inside-lap, or lap on the exhaust-side, when it exists to any extent, is given to the valve to delay the release of the steam, but in engines that work at a good speed no inside lap is given, more than is just sufficient to cover the ports on the exhausting side to prevent leakage of steam when the valve is at its half-stroke.

Lap of Valve necessary to cut the Steam off at a given part of the Stroke.—*Rule:* From the length of stroke in inches, deduct the distance in inches moved by the piston when the steam is cut off, divide the remainder by the stroke of the piston in inches, and extract the square root of the quotient, then, multiply the result by half the stroke of the valve in inches, and deduct half the lead from the product, the remainder will be the required lap in inches.

Point of Cut-off of Steam from a given Lap.—*Rule:* To the lap of the valve on the steam-side in inches add one half the lead, then divide by half the travel of the valve in inches, and multiply the square of the quotient by the length of stroke of the piston in inches; deduct the product from the length of stroke of the piston in inches, and the remainder will be the distance in inches that the piston moves when the steam is cut off.

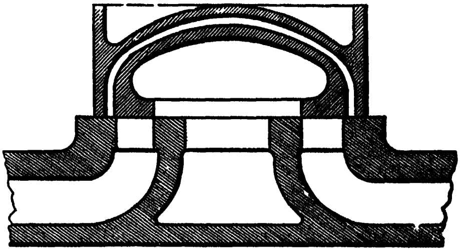


Fig. 19.—Trick-Slide-Valve.

A Trick-Slide-Valve, shown in Fig. 19 has a passage formed on the back of the valve through which steam enters the port, as well as from the end of the valve, for the purpose of admitting steam to the cylinder with the smallest possible travel of the valve. The valve and seat are so arranged that the instant the outside edge of the valve begins to open the steam-port, steam flows through the passage in the valve into the steam-port and the piston receives the full pressure of the steam at the instant of admission. This form of valve favours the attainment of high-speed.

The Slide-Valve, shown in section in Fig. 20, is an improved form of Trick-valve applied to single-cylinder condensing-engines and to the low-pressure cylinder of compound, or multiple-expansion, engines. Its object is to supply steam for cushioning the piston to balance its momentum, there being little steam left in the cylinder available for compression when the vacuum is good. This is effected by employing the steam-passage at the back of the valve for transferring steam from one side to the other of the piston. When the piston is nearly at the end of its stroke, a communication is formed by the valve with each end of the cylinder and steam passes from one end to the other, as shown by the arrows in Fig. 20, and the ports and passages are filled with steam which would otherwise pass to the condenser. The quantity of steam contained in the clearance-spaces is seldom less

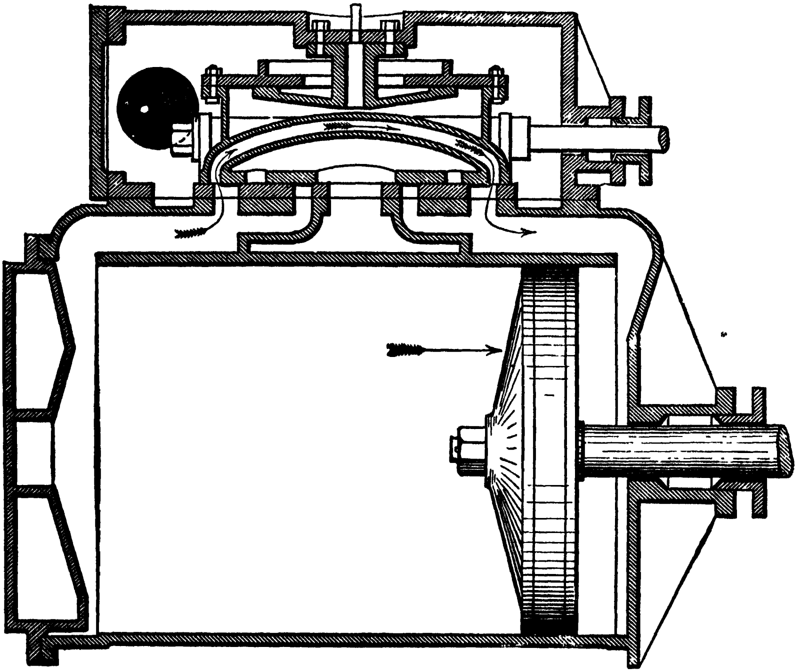


Fig. 20.—Cylinder, with Slide-Valve and Relief-Frame.

than six per cent. of the quantity of steam used, therefore a saving is effected of that amount of steam.

A Piston Valve is shown in Fig. 21, and with the Robey medium stroke engines is operated by an eccentric, Fig. 22, mounted on the crankshaft, so arranged that the cut-off may be regulated from ¼ to ¾ of the stroke, the lead remaining constant. Full advantage, therefore, can be obtained from the use of high pressure steam, as the ratio of the expansion of the steam can be varied to suit the power the engine has to develop. By adjusting one nut the desired position can be fixed and the direction of rotation varied at will.

Fig. 21.—A Piston Valve.

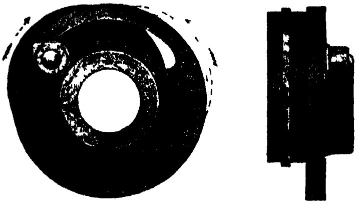


Fig. 22.—An Adjustable Eccentric.

The flat slide-valve is generally accentuated by a simple eccentric keyed on to the crank shaft and is equivalent to a crank of equal throw. Usually it is fixed at an angle of a little more than 90° ahead of the crank. When a slide-valve is worked by link-motion, two eccentrics are employed which form an angle of 180° minus twice the angle of advance. The position of the eccentric is shown in Fig. 23, in which the line A B represents the position of the crank, at the beginning of the stroke of the piston and C, the centre of the eccentric. The resistance to be overcome by an eccentric is the friction of the slide-valve, which is proportional to area of the valve exposed to steam-pressure multiplied by the pressure of the steam. The friction of a slide-valve generally averages about one-tenth of the load upon it.

The Throw of an Eccentric is the distance it is thrown out of the centre, or the amount of eccentricity of the eccentric. It is the distance from the centre of the shaft on which the eccentric is keyed to the centre of the eccentric: or it is the radius of a circle described during one revolution of the eccentric, equal line, A D, Fig. 23. When the eccentric works the valve direct, the throw of the eccentric is equal to one-half the travel of the valve; or equal the greatest width the port is opened for the admission of steam + lap of the valve.

Advance of an Eccentric.—The angular-advance of an eccentric is the angular measurement of the arc E in Fig. 23. The linear-advance of an eccentric is the distance travelled by the slide-valve during the time the eccentric moves through its angular-advance. It is equal to the lap plus the lead of the valve, and equal A F, Fig. 23.

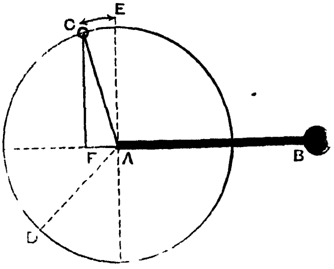


Fig. 23.—Diagram showing the position, throw, and advance of an Eccentric.

Position of the Keybed of the Eccentric.—The position of the eccentric-sheaves and keybeds on a crank-shaft, neglecting the obliquity of the eccentric-rod, may be found as follows:—Place the crank in the position shown in Fig. 24, with the horizontal centre-line A B level: draw the vertical centre-line C D. On the end of the crank-shaft, from its centre O, with a radius equal to one-half the travel of the slide-valve, describe the travel-circle E. Draw F G, parallel to C D, at a distance equal to the sum of the lap and lead of the valve. Draw the radial lines O H and O I through the points of intersection of the travel-circle with the line F G. Then, if the keyway is cut on the centre-line, or throw-line, of the eccentric, O H is the centre-line of the forward-eccentric, and O I that of the backward-eccentric, on which lines the keybeds must be cut in the crank-shaft.

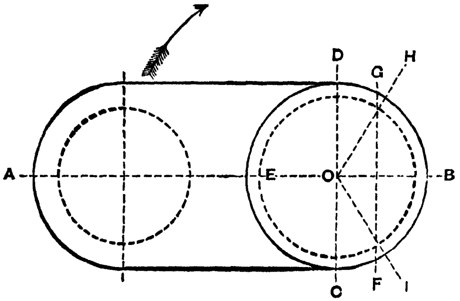


Fig. 24.—Diagram showing the position of the Keybed of an Eccentric.

Steam-Ports and Passages.—There is generally more or less loss of initial pressure from the resistance due to friction in the passing of the steam through valves, pipes, steam-chest, ports, and passages to the cylinder. The ports and passages of a cylinder should be sufficiently large to permit the steam to follow the piston to the point of cut-off without loss of pressure. As the steam is exhausted, in most cases, from a cylinder through the same passages and ports by which it entered, the size of the steam-ports and passages should be proportioned to the velocity of the exhaust-steam. If the ports and passages are too large, it causes loss of steam from excessive steam-space. If they are too small, the steam cannot follow the piston without expanding before being cut off, and there is loss of efficiency from wire-drawing the steam in passing in and out of the cylinder. The velocity of the exhaust-steam through the ordinary ports and bent passages of a cylinder with a slide-valve may be 75 feet per second, and should not exceed = 95 feet per second × 60 = 5700 feet per minute. For very short and straight passages, it may be = 125 feet × 60 = 7500 feet per minute. The area of each steam-port and the sectional area of each steam-passage, P, in square inches, may be found by this Rule:—

$$P = \frac{\text{Area of cylinder in square inches} \times \text{piston-speed in feet per minute}}{\text{Velocity of exhaust-steam in feet per minute.}}$$

Steam-Port-Opening.—The area of the steam-passages and ports, is generally at least double that of the greatest opening of the port by the slide-valve for the admission of steam, in order to provide free exhaust of the steam. The velocity of the steam through the port-opening, on its admission to the cylinder should not be higher than 11,400 feet per minute, through ordinary bent passages, and 15,000 feet per minute through very short straight passages.

The area of the steam-port-opening, O, in square inches, may be found by this Rule:—

$$O = \frac{\text{Area of cylinder in square inches} \times \text{piston-speed in feet per minute}}{\text{Velocity of steam through the steam-port-opening in feet per minute.}}$$

The steam is generally more or less wire-drawn, resulting from the valve not opening and closing the port quickly enough. The loss of pressure due to wire-drawing the steam, from the gradual opening and closing of the steam-port, may be partly provided for by making the cut-off a little later than theoretically required.

Steam-Pipe.—In order to prevent loss of pressure between the boiler and the engine, the velocity of the steam through a steam-pipe should not in ordinary cases, exceed 85 feet per second × 60 = 5100 feet per minute. For very short, straight steam-pipes, the velocity may be = 6600 feet per minute. The area of the steam-pipe, S, may be found by this rule:—

$$S = \frac{\text{Area of cylinder in square inches} \times \text{piston-speed in feet per minute}}{\text{Velocity of steam through the steam-pipe in feet per minute.}}$$

Steam-pipes should be as short and straight as possible.

STEAM-ENGINE GOVERNORS.

The Function of a Governor is to regulate the supply of steam to the cylinder according to the variations or sudden changes in the load on the engine. The efficiency of a governor depends principally upon its sensitive-

The Action of the Governor of a steam-engine is controlled by two forces, viz., centrifugal force, or the tendency of the revolving balls to fly away from the spindle or vertical axis, and centripetal force, or the tendency of the balls to hang in a vertical line from the centre of the pin suspending the arm, due to the force of gravity.

To find the centrifugal force of a governor in terms of the weight of the balls. Multiply the square of the number of revolutions per minute by the radius of the circle described by the centres of the balls in inches, and divide the product by the constant number 35,226.

To find the centripetal force of a governor in terms of the weight of the balls. Divide the horizontal distance of the balls from the centre of the suspending pin, by the vertical height of the same centres.

Simple Governors, shown in Fig. 25.—The centre of the suspension of the arms should invariably be placed in the centre of the spindle, unless it be placed beyond it, as in Fig. 26; because it is essential for a governor to work with the least possible variation in speed, and the placing of the point of suspension away from the centre of the spindle causes considerable variation in velocity. The variation in velocity increases as the distance is increased of the centre of the suspension-pin from the centre of the spindle. Although wrong in principle, the arms are frequently hung away from the centre of the spindle, as in Fig. 27; and in calculating such governors, the vertical height is to be taken from the plane-line, P, to the top of the cone, T, instead of the actual centre of suspension.

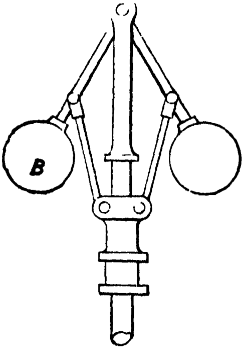


Fig. 25.—Simple Governor.

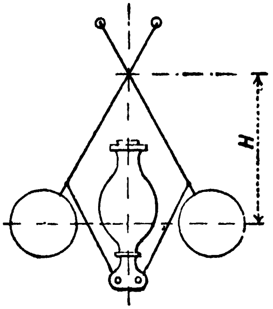


Fig. 26.
Cross-armed Governor.

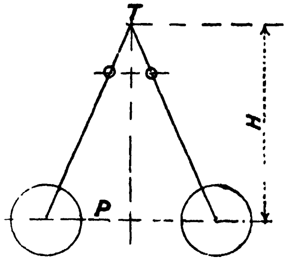


Fig. 27.—Governor-Arms.

To find the power of a governor, multiply the weight of the balls in lbs. by the vertical height they are lifted.

To find the vertical height, H, between the point of suspension and the plane of revolution, P, divide the constant number 187·5 by the number of revolutions of the governor, and square the quotient, which will give the height in inches.

Diameter of Cast-iron Balls for Ordinary Governors, B.—The weight of the balls must be sufficient to overcome the resistance of the valve and its connections. In ordinary cases the diameter of each ball may be equal to one half the height of plane-line, H, in inches.

Length of Governor-Arms.—First determine the vertical height from the plane of revolutions to point of suspension of arm, H, Fig. 28; then set out the centre-lines of the arms at an angle of 60°, as their position at the proper speed of the governor, and where the said centre-lines of arms cut the plane-line will be the centres of the balls, and the length of arm will be the distance between the centre of suspension and the centre of the ball thus found. The speed required to maintain the balls at that height is obtained by the following rule:—

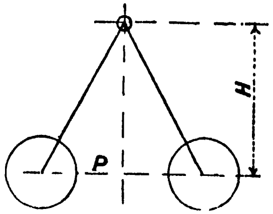


Fig. 28.—Governor Arms

To find the Speed of Simple Governors, divide the constant number, 187·5, by the square root of the vertical height in inches between the plane of revolution and centre of suspension, and the quotient will be the number of revolutions per minute required to maintain the balls at that height.

Governors are driven from the engine crank-shaft by means of pulleys or gearing, and the diameter of pulley, or number of teeth in the wheel, to produce the proper velocity may be found by the following rules:—

To find the Diameter of Pulley (or number of teeth in the wheel) on the driving shaft of the governor. Multiply the number of revolutions of the engine per minute by the diameter of pulley (or number of teeth in the wheel) on the engine crank-shaft, and divide by the required number of revolutions per minute of the governor.

To find the diameter of pulley (or number of teeth in the wheel) on the engine crank-shaft. Multiply the diameter of pulley (or number of teeth in the wheel) on the governor driving-shaft by the number of revolutions per minute of the governor, and divide by the number of revolutions per minute of the engine.

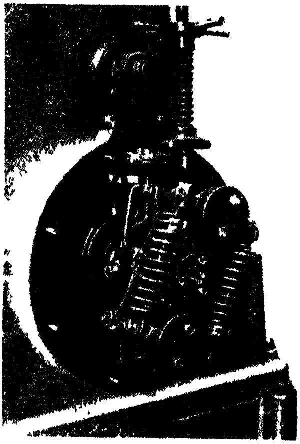


Fig. 29.—Browett-Lindley Governor with Cover Removed.

Spring Governor.—A spring loaded governor of centrifugal type is shown in Fig. 29. It is fixed to the crank-shaft end and acts directly on the throttle valve. Normally it is set to control the speed of the engine within 3 per cent. between no load and full load.

Cross-armed Governor with Centre-weight, Fig. 26.—In this class of governor, the centre of suspension must be calculated from the point where the arms cross each other in the centre-line of the spindle, and the vertical height is the distance from that point to the plane of revolution. By crossing the arms in this way the governor becomes very sensitive; when the speed is increased, the point of intersection of the crossed arms rises at the same rate as the plane of revolution, and the governor balls will remain in equilibrium in every angular position at the proper speed of the governor. This kind of governor is run at a high speed; the proportions may be calculated by the following rules for centre-weighted governors.

STEAM-ENGINE GOVERNORS WITH CENTRE-WEIGHT.

Governor with Centre-weight, shown in Fig. 30.—This form of governor requires to be driven at a high speed, so that the centrifugal force of the balls may overcome the gravity of the centre-weight. Its advantages over the simple governor are: its extreme sensitiveness, whereby uniformity of speed is maintained under varying and sudden changes of the load on the engine; and its great power. enabling a much smaller governor to be used.

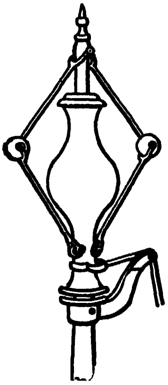


Fig 30.—Centre-weighted Governor.

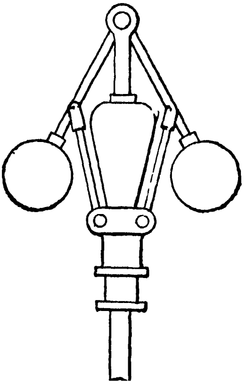


Fig. 31.—Governor, with Centre-weight.

To find the vertical height from the plane of revolution to the point of suspension of a governor with centre-weight. First, fix upon the number of revolutions, divide the constant number 187·5 by the number of revolutions the balls will make when the engine is at its proper speed, and square the quotient, which will give the height in inches for an ordinary governor, H; then add together the weight of the revolving balls and twice the weight of the centre-weight, which sum multiply by the height, H (found as for an ordinary governor), and divide the product by the sum of the weights of the revolving balls, the quotient will be the height of a centre-weighted governor. If the centre-weight is hung by links at a point in the arm above the centre of the balls, like Fig. 31, then use the above rule, but instead of twice the weight of the centre-weight named above, use the product of twice the weight of the centre-weight, multiplied by the result of the length between the centre of suspension of the arm and the point where the link is hung on to the arm, subtracted from the length between the centre of the ball and the centre of suspension of the arm.

To find the weight of the centre-weight. Find the vertical height by the above rule, both for a centre-weighted governor and for a simple governor, both at the same speed, then multiply the weight of the two revolving balls by the vertical height thus found for the centre-weighted governor, and divide the product by the vertical height thus found for a simple governor, which will give twice the weight of the centre-weight plus the two revolving balls, then subtract the weight of the two balls from that result, and divide the remainder by two, which will give the weight of centre-weight required.

The diameter of the revolving balls for governors like Fig. 30 should be equal to about $\frac{1}{5}$th of the vertical height from the plane of revolution to the centre of suspension of the arm. *The speed* of these governors is from 200 to 300 revolutions per minute.

Example of the rules for Centre-weighted Governors.—A governor like Fig. 30 revolves at 260 revolutions per minute, the weight of the balls is 3 lbs. each, the weight of the centre-weight is 84 lbs., required the vertical height. Then $\frac{187\cdot5}{260} = \cdot71 \times \cdot71 = \cdot504$, vertical height, and $\cdot5\ (6+168) = 87$, and $\frac{87}{6} = 14\cdot5$ inches, vertical height. Taking these particulars to find the centre-weight, then $14\cdot5 \times 6 = 87$ and $\frac{87}{\cdot5} = 174$, $174 - 6 = 168$, and $168 \div 2 = 84$ lbs., the weight of centre-weight required.

Centre-weighted governors are in some cases fitted with a spiral-spring on the spindle, to assist the weight, as shown in Fig. 32.

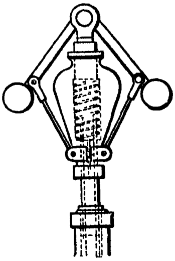


Fig 32.—Governor, with Centre-weight, assisted by a spiral-spring.

Shifting-Eccentric Governors.—This type of governor, shown in Fig. 33, regulates the supply of steam to the cylinder by controlling the cut-off valve. It is fixed on the crank-shaft of an engine and the movement of the centrifugal weights shifts the eccentric a certain angular distance, and alters the point of cut-off of the steam by the valve. The gravity of one weight neutralizes the other, and the centripetal force is derived from spiral-springs. To steady the action of the eccentric, and prevent irregularity of its motion, a dash-pot is frequently attached to the arm which carries the centrifugal weight as shown in Fig. 34.

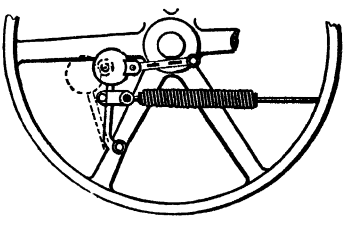


Fig. 33.—Shifting Eccentric Governor.

The governor, shown in Fig. 35, has a spring, s, placed between the dash-pot and the moving part of the governor, for the purpose of obtaining stability and efficient adjustment of the long spring, D. This governor efficiently regulates the supply of steam to the varying conditions of the load.

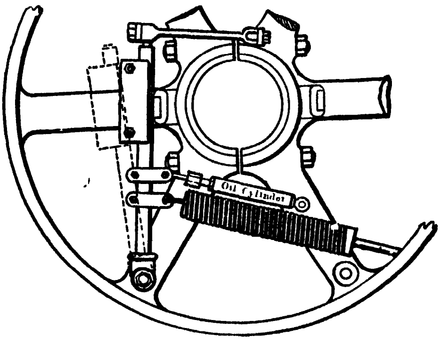


Fig. 34.—Shifting-Eccentric Governor, with Dash-Pot.

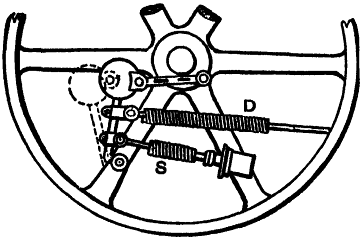


Fig. 35. Shifting Eccentric-Governor.

PROPORTIONS OF HIGH-PRESSURE NON-CONDENSING STATIONARY STEAM-ENGINES.

The Proportions of Steam-Engines are generally determined by empirical rules based upon experience, consequently there is great diversity of practice, and the proportions adopted by different engine makers vary considerably. The modern steam engine is highly efficient, extremely flexible and most reliable, and when the production of power can be combined with any form of process heating will provide a prime move, unsurpassed in economy by any other type of plant. · In the majority of small industrial power plants steam is required for one purpose or another, and when it is necessary to generate steam and also provide power, it is usually advantageous to install a steam engine even when the maximum economy of combined power and heating cannot be attained.

The engine illustrated in Fig. 36 is manufactured in sixteen standard sizes and developed the powers given in table 3, page 36. This type of engine has been specially designed to meet the demand for a light, cheap and efficient engine running at moderately high speed, and is suitable for steam pressure up to 150 lb. per sq. in. Being self-contained it is practically independent of foundation and can be bolted to a beam or an upper floor. These engines are constructed by Messrs. Robey & Co., Ltd,, Lincoln, and can be made either hand, i.e. when standing at the cylinder end of engine and looking towards the crankshank, the flywheel can be on the right or left as desired.

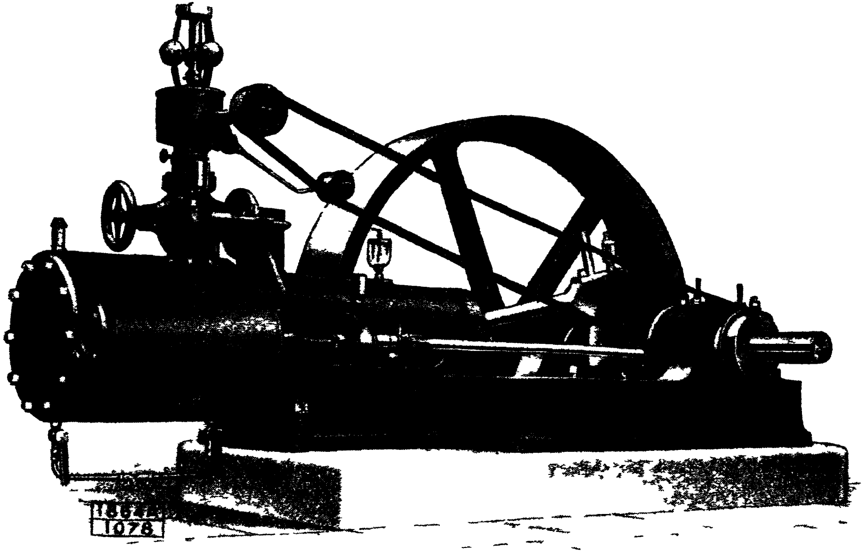


Fig 36 —Horizontal Non Condensing Engine. (Messrs Robey & Co, Lincoln)

Table 3.—HORIZONTAL MEDIUM STROKE ENGINES.

No	Effective Horse Power				CYLINDER		FLYWHEEL				Dia of Steam Pipe	Dia of Exhaust Pipe	Space Required			
	60 lbs		100 lbs		Dia	Stroke	Dia		Wid	Revs per Min			Length		Width over Crank	
	Econ.	Max	Econ	Max	In	In	Ft	In	In		In	In	Ft	In	Ft	In
1	2	3	—	—	4	5	1	9	3	300	¾	1	3	4	2	3½
2	2½	3½	—	—	4½	6	2	9	4	280	1	1¼	4	6	2	7½
3	—	—	6½	8	4½	7	3	0	5	280	1¼	1½	5	3	3	3½
4	5½	8	—	—	5¼	7	3	0	5	280	1¼	1½	5	3	3	3¼
5	—	—	10	12	5¾	8	3	6	5	260	1¼	1½	5	8	3	3¼
6	8	12	—	—	7	8	3	6	5	260	1¼	1½	5	8	3	3¼
7	—	—	14	17	6½	9	4	0	6	230	2	2¼	6	3	3	8
8	12	17	—	—	8½	9	4	0	6	230	2	2¼	6	3	3	8
9	—	—	20	24	8½	10	4	6	7	210	2	2¼	7	3	4	3
10	17	24	—	—	10	10	4	6	7	210	2	2¼	7	3	4	3
11	—	—	26	32	9½	12	5	0	9	175	2¼	2½	8	2	4	6
12	20	29	—	—	11	12	5	0	9	175	2¼	2½	8	2	4	6
13	—	—	35	46	10½	15	5	6	11	150	2½	3	9	6	5	2
14	27	38	—	—	12	15	5	6	11	150	2½	3	9	6	5	2
15	—	—	43	57	12	16	6	0	12	130	3	3½	10	3½	6	3
16	32	45	52	64	13½	16	6	0	12	130	3	3½	10	3½	6	3

The Horizontal Engine, illustrated in Fig 37 is manufactured by Messrs Marshall, Sons & Co, Gainsborough, in fourteen standard sizes The particulars of this engine are given in table 4

Table 4 —SIZES OF HORIZONTAL SINGLE CYLINDER ENGINES

SIZE		R P M	NON CONDENSING				CONDENSING			
			Effective H P at Boiler Pressures				Effective H P at Boiler Pressure			
			80 lbs Load		100 lbs Load		80 lbs Load		100 lbs Load	
Dia	Str		Econ	Max	Econ	Max	Econ	Max	Econ	Max
7″	20″	135	13	21	14	27	13	25	14	31
8″	20″	135	17	28	18	35	16	33	18	41
9″	24″	125	23	39	25	49	22	46	24	57
10″	24″	125	29	48	31	61	28	58	31	70
11″	30″	110	40	65	43	81	37	77	41	95
12″	30″	110	48	76	51	97	45	90	48	111
13″	36″	100	60	98	62	124	57	116	62	142
14½″	36″	100	75	121	78	155	71	146	78	176
16″	42″	86	91	150	95	187	87	176	94	216
17″	42″	86	103	168	108	212	99	200	107	245
18″	42″	86	115	189	121	237	110	224	126	276
19″	42″	86	129	215	135	266	123	250	134	306
20″	48″	75	141	232	149	293	136	276	148	340
22″	48″	75	173	282	180	355	168	335	179	410

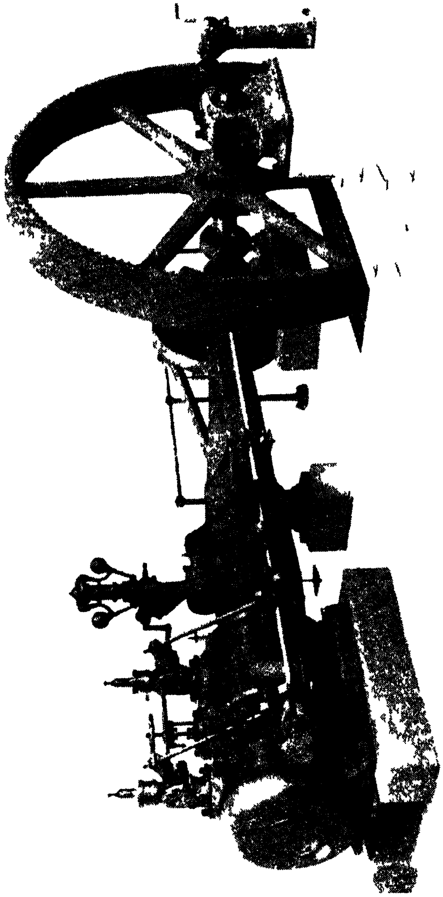


Fig 37 —Horizontal Single Cylinder Condensing or Non Condensing Engine with Drop Valves (Messrs Marshall, Sons & Co, Gainsborough)

Piston-Speed.—The velocity with which steam can drive a piston is infinitely greater than can be adopted in practice. The speed of piston in feet per minute is found by multiplying twice the length of stroke in feet by the number of revolutions per minute of the crank-shaft. A piston with a given pressure upon it, will exert power in direct proportion to its speed, therefore an engine to work economically should work at as high a speed as is possible without heating and vibration. A high speed enables large measures of expansion to be used, and gives a smooth and uniform motion. A high speed engine requires wide bearings, and the momentum, or force stored up in its moving parts, should be accurately balanced, to enable it to run steadily without tremor; the piston can be balanced by compression, and the large end of the connecting-rod, and the crank, should be balanced by a counterweight revolving opposite to the crank, so that both may revolve in the same plane of revolution. The piston-speed varies in different types of steam-engines from 250 to 1200 feet per minute. Stationary non-condensing steam-engines range from 250 to 300 feet per minute. The average piston-speed of modern stationary non-condensing simple steam-engines is 260 feet per minute. The piston-speed of steam-engines using high rates of expansion, should not be less than about 450 feet per minute.

Area of Steam-cylinder per nominal Horse-power.—It is usual to provide 9 square inches of cylinder-area for each nominal horse-power of a stationary non-condensing simple steam-engine.

The Diameter of Cylinder required to develop a given nominal Horse-power may be found by this Rule—multiply the nominal horse-power by 9, extract the square root of the product and multiply by 1·1283. For instance, a non-condensing simple steam-engine of 10 nominal horse-power, requires a cylinder of $10 \times 9 = \sqrt[2]{90} = 9{\cdot}4868 \times 1{\cdot}1283 = 10{\cdot}704$, or say $10\frac{3}{4}$ inches diameter.

The Diameter of Cylinder required for the development of a given Indicated Horse-power may be found by this Rule:—

$$\sqrt[2]{\frac{33000 \times \text{Indicated horse-power}}{\cdot 7854 \times \text{mean pressure} \times \text{piston-speed}}}$$

For instance, the diameter of cylinder required for a steam-engine of 25 indicated horse-power, making 80 revolutions per minute; length of stroke 2 feet; mean pressure of steam 30 pounds per square inch is—

$$\sqrt[2]{\frac{33000 \times 25 \text{ Indicated horse-power}}{\cdot 7854 \times 30 \times (2 \text{ feet stroke} \times 2 \times 80)}} = 10{\cdot}48 \text{ inches,}$$

or say, in round numbers, $10\frac{1}{2}$ inches diameter.

Steam-Cylinders should be made of best close-grained cast-iron, not less than twice cast, as hard as it can be worked, and perfectly free from honeycomb or other defects. They should be accurately and smoothly bored, and have all joints and surfaces planed or turned and scraped to a true surface, so that perfectly steam-tight joints may be obtained. They should be bellmouthed at each end, to prevent the formation of a ridge due to wear, which would cause a knock or thump at each end of the stroke. Good mixtures of metal for cylinders are given at page 241. A cylinder of a horizontal steam-engine is shown in section in Fig. 38. Cylinders should be clothed with silicate-cotton, and lagged with wood to prevent loss from radiation of heat and initial condensation of steam. The joint of the steam-chest-cover may be made either with copper-wire, lead-wire, or with a strand of asbestos-packing, laid twice round the joint. With good faces a red lead paint is sufficient.

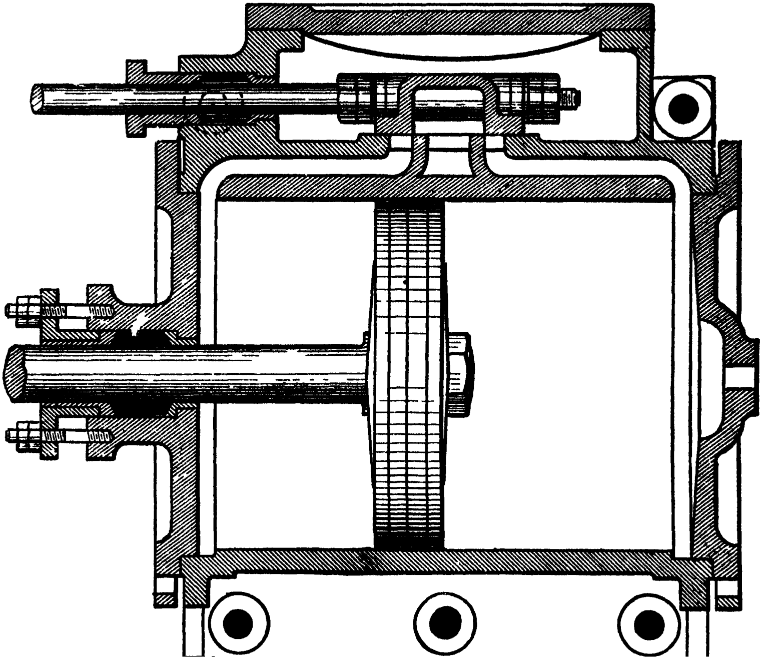


Fig. 38.—Cylinder of a Horizontal Steam Engine.

Thickness of Steam-Cylinder.—The following is the average thickness of cylinders of cast-iron, including allowance for reboring, for the ordinary pressures of steam used in stationary steam-engines

Diameter of cylinder, in inches . .	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	22	24
Thickness of metal, in inches . .	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	$\frac{15}{16}$	1	1	$1\frac{1}{16}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{5}{16}$	$1\frac{3}{8}$

Thickness of Cylinder-Ribs=three-quarters the thickness of the metal of the cylinder.

Thickness of Cylinder-Flanges = thickness of cylinder × 1·25.

Thickness of Metal of Steam-Passages = three-quarters the thickness of the cylinder.

Thickness of Cylinder-Covers = thickness of cylinder-flange multiplied by ·83.

Thickness of Sole-Plate of Cylinder = thickness of cylinder multiplied by 1·25.

Area of Steam-Port.—Sufficient area of steam-port should be provided to permit free ingress and egress of steam, and obtain a moderate velocity of steam. The area of the steam-ports, as shown in Fig. 39, should be proportioned to the speed of the piston, as explained on page 29. The area of each steam-port may, in a general way, be equal to the area of the cylinder in square inches divided by 12. The distance between the valve-seat and the cylinder should be as short as possible. The steam-passages should be as straight and smooth as possible.

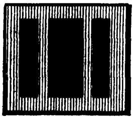


Fig. 39.
Cylinder-Ports.

Length of Steam-Port.—The steam-port should be as long as possible, in order to obtain a large area of opening of the steam-port for the admission of steam with a small movement of the valve. The length of the steam-port may be equal to the diameter of the cylinder in inches multiplied by ·88.

Width of Steam-Port = area of steam-port divided by the length of the steam-port.

Width of Exhaust-Port = width of steam-port multiplied by 2·25.

Width of Bridge = width of steam-port divided by 1·37.

Area of Steam-Pipe.—The area of the steam-pipe may be found by the rule on page 29. It may, in a general way, be equal to the area of the cylinder in square inches divided by 16.

Area of Exhaust-Pipe.—The area of the exhaust-pipe may be found by the rule on page 29. It may, in a general way, be equal to the area of the cylinder in square inches divided by 12.

Diameter of Piston-Rod.—The diameter of a piston-rod of wrought-iron may be = diameter of cylinder in inches × ·02 × square root of the initial pressure of the steam. For a piston-rod of steel, use a multiplier of ·016 instead of ·02. For instance, the size of a piston-rod for a cylinder of 12 inches diameter for an initial pressure of steam of 81 pounds per square inch is $= 12 \times {}^{\cdot}02 \times \sqrt[2]{81} = 2{\cdot}16$ or say $2\frac{3}{16}$ inches, the diameter of a piston-rod of wrought iron; or $12 \times {}^{\cdot}016 \times \sqrt[2]{81} = 1{\cdot}728$, or say $1\frac{3}{4}$ inches, the diameter of a piston-rod of steel. For pressures of steam up to 100 lbs. per square inch, the diameter of the piston-rod may, in a general way, be = diameter of cylinder divided by 6·2.

Diameter of Piston-Rod Stuffing-Box = diameter of piston-rod multiplied by 1·8.

Depth of Piston-Rod Stuffing-Box = diameter of piston-rod multiplied by 1·6.

Depth of Gun-Metal Bush at bottom of Stuffing-Box = one-third diameter of piston-rod.

Thickness of Flange of Gland = one-fourth more than the thickness of the gland.

Thickness of Metal round the Stuffing-Box = thickness of the gland multiplied by 1·5.

In some cases it is convenient to make the gland in halves, notched one into the other, so that it may be removed while the piston-rod is in its place.

Diameter of Slide-Valve-Spindle.—The diameter of the spindle of a slide-valve, when of wrought-iron, may be=diameter of cylinder in inches × ·0113 × square root of the initial pressure of the steam. For a valve-spindle of steel, use ·009 as a multiplier instead of ·0113. For instance, the size of a valve-spindle for the slide-valve of a cylinder of 12 inches diameter, initial pressure of steam 81 pounds per square inch, is $= 12 \times \cdot0113 \times \sqrt[2]{81} = 1\cdot22$, or say 1¼ inches, the diameter of a wrought-iron valve-spindle; or $12 \times \cdot009 \times \sqrt[2]{81} = \cdot972$, or say 1 inch the diameter of a valve-spindle of steel. For pressure of steam up to 100 pounds per square inch, the diameter of the slide-valve-spindle may, in a general way, be = one-tenth the diameter of the cylinder.

Packing for the Stuffing-Boxes of Piston-Rods and Valve-Spindles.—The simplest form of packing used for small engines and pumps consists of woven asbestos. Semi-metallic packing made of fabric and non-friction metal should be used when possible.

Metallic-Packing for Stuffing Boxes.—The stuffing-boxes of engines using steam of very high pressure should be packed with metallic-packing. When it is applied in the form of rings it may consist of one of the alloys for this purpose given further on. An efficient arrangement of metallic-packing, having the packing-rings compressed by a spiral-spring, is shown in Fig. 40. Semi-metallic-packing is formed of very fine metallic wire plaited with asbestos into a square rope, and is applied in the same manner as ordinary-packing. When the wire becomes warm, it expands and fills the stuffing-box. The elastic and flexible nature of the packing effects a yielding pressure on the piston-rod, but sufficient to secure a steam-tight stuffing-box.

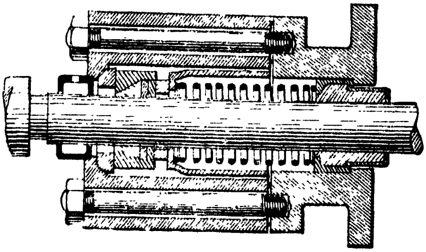


Fig. 40.—Metallic-Packing for Piston-Rod.

Lubricant for Steam-Cylinders.—The wear and friction of piston-rings and valves is diminished by efficient lubrication, which should be constant and automatic. A good quality lubricant should always be used for cylinders. Cylinder-oil consisting of a mixture of mineral oil and graphite will give the best results. An engine will work without cylinder-lubrication, but unless specially designed, it is at the expense of increased friction and wear of the piston-rings and cylinder.

Outside Lap of Slide-Valve.—The lap of a slide-valve is determined by the distance the piston is required to travel before the steam is cut off, which may be found by the rule on page 25. Engines made on stock have frequently sufficient lap to cut off the steam at one-half the stroke.

Inside Lap of Slide-Valve = $\frac{1}{16}$ inch.

Stroke of Slide-Valve.—Add together the width of steam-port and the outside lap and multiply by 2, the product will be the stroke of the valve.

The Face of a Slide-Valve should be planed true, but need not be scraped, because it soon becomes beded and polished by wear.

Clearance between the Piston and Cylinder-Cover at each end of the Stroke should be as small as practicable: in small engines it may be = diameter of cylinder divided by 32.

The Length of Stroke of engines of strong construction is usually = diameter of cylinder multiplied by 2. Engines of light construction have generally a length of stroke = diameter of cylinder multiplied by 1·5.

Pistons are generally made of cast-iron of the same mixture of metal as that of the cylinder, but in some cases they are of steel, and various alloys. They are made in a great variety of forms of construction. The width of the piston is generally equal to from one-fifth to one-fourth the diameter of the cylinder. A simple and very efficient form of piston is shown in Fig. 41. It consists of a disc of metal fitted with two cast-iron packing-rings, $\frac{3}{4}$ inch wide, and $\frac{1}{2}$ inch thick, spaced $\frac{3}{4}$ inch apart in turned grooves. The rings are turned $\frac{1}{2}$ inch larger in diameter than the cylinder; a piece is cut out of the ring, and it is sprung over the end of the piston into its place. The rings only require about 5 lbs. of tension to keep them steam-tight. A large piston of this description has the body cast hollow, to lighten it, and the packing-rings are inserted in a cover which is bolted to the piston as shown in Fig. 42. Pistons of this form, under 18 inches diameter, may have two packing-rings; from 18 to 26 inches diameter three rings, and from 28 to 50 inches diameter four rings. Another kind of piston is shown in Fig. 43. It has packing-rings

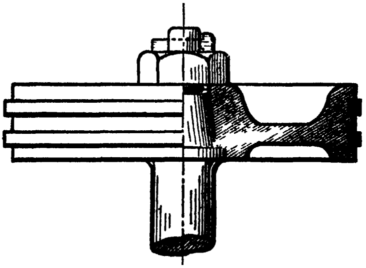


Fig. 41.—Piston with solid body

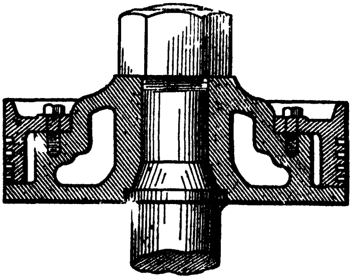


Fig. 42.—Piston with cov

of cast-iron, expanded by a V-shaped spring-ring. The packing-rings are expanded by screwing down the cover of the piston. A large piston of another form, cast hollow or box-shaped, and fitted with cast-iron packing-rings, is shown in Fig. 44.

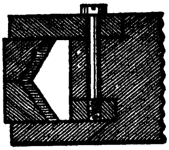


Fig 43.—Section of Piston with V-shaped Rings.

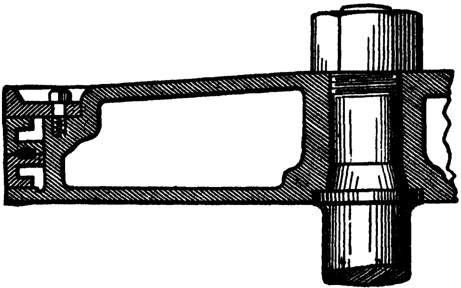


Fig. 44.—Large Piston.

Piston-Rings.—Cast-iron works the best of all metals upon cast-iron, and is a good material for piston-rings. Cast-iron rings lose their elasticity when reduced by wear to five-eighths of their original thickness. The elasticity of the rings may be increased by hammering them on the inside. An alloy has been successfully used in marine engines, consisting of copper, 15 parts; tin, 5 parts; these rings, it is said, require no lubrication, do not score the cylinder, are very durable, and cause very little wear in the cylinder, which they soon work up to a polished face. Piston-rings should be cut diagonally to prevent scoring the cylinder. The piston-rings should traverse the entire bore of the cylinder, and a little beyond into the counter-bore, to avoid the formation of a ridge.

Diameter of Crank-Shaft.—This should be proportioned to the strain upon it, by the rules on pages 149–151 ; but in a general way, the diameter of a wrought-iron crank-shaft may be = to the diameter of cylinder multiplied by ·4. The diameter of a steel-crank-shaft may be = diameter of cylinder multiplied by 3·2.

Diameter of neck of crank-shaft, recessed in the crank-shaft = Diameter of crank-shaft multiplied by ·8. The fillet or corner of the neck should be formed with a good radius, to obviate fracture. Recessing the necks weakens the shaft, and it is better to form the necks by collars on the shaft.

Length of neck of crank-shaft = diameter of crank-shaft multiplied by 1·6 for moderately high speeds, and by at least 2 for high speeds.

Crank, Cast-iron, of the form shown in Figs. 45 and 46.—Diameter of boss for crank-shaft = diameter of shaft multiplied by 2.

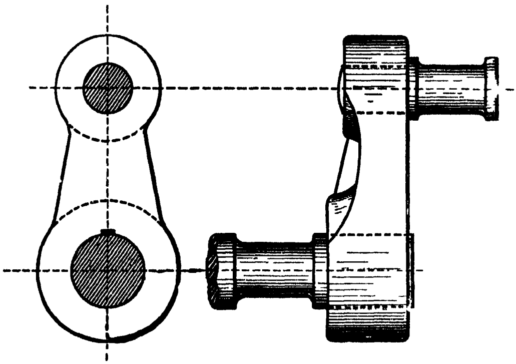
Depth of boss = diameter of shaft.

Crank to be shrunk on and keyed on with a key in width = to $\frac{1}{4}$th the diameter of shaft.

Thickness of key = width of key multiplied by ·42.

Diameter of the boss for crank-pin = diameter of the crank-pin multiplied by 2·25.

Depth of boss for crank-pin = diameter of crank-pin multiplied by 1·5. Crank-pin to be shrunk in and riveted at the back.



Figs. 45 and 46.—Cast-Iron Crank.

Thickness of web of crank = diameter of crank-pin: and a strong rib in the centre should connect the two bosses.

Crank, Wrought-Iron. — Diameter of boss for crank-shaft = diameter of shaft multiplied by 1·75.

Depth of boss = diameter of shaft multiplied by ·87.

Diameter of boss for crank-pin = diameter of crank-pin multiplied by 2.

Depth of boss for crank-pin = diameter of crank-pin multiplied by 1·4.

Thickness of web of crank = diameter of crank-pin.

Crank-Pin.—Diameter of crank-pin = diameter of cylinder multiplied by ·20 to ·24. It is frequently = diameter of the neck of crank-shaft multiplied by ·66.

Length of crank-pin = diameter of crank-pin multiplied by 1·5.

When a crank-pin becomes strained by wear, and is not perfectly parallel to the crank-shaft, it is liable to heat, or knock.

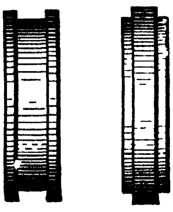


Fig. 47. Fig. 48.
Eccentrics.

Eccentric.—The eccentric or eccentric-tumbler is either formed with a recess on its circumference to guide the strap, as shown in Fig. 47, or with a projection as shown in Fig. 48. The latter design occupies the least room on the shaft and favours lubrication.

Throw of eccentric when it works the valve direct = $\frac{1}{2}$ the travel of the slide-valve.

Width of the recess for the eccentric-strap = diameter of cylinder multiplied by ·18.

Depth of recess in eccentric = from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch according to size.

Thickness of flange on each side of the recess = $\frac{1}{4}$ inch to $\frac{1}{2}$ inch according to size.

Diameter of boss of eccentric = diameter of shaft multiplied by 1·6.

Depth of boss of eccentric = diameter of shaft multiplied by ·7.

Eccentric-Strap.—Thickness when of cast-iron = to its width multiplied by ·67. An eccentric-strap is shown in Fig. 49, the rod of which is formed with a butt-end for ready adjustment.

Thickness when of gun-metal = the width of strap multiplied by ·53.

When the strap is iron lined with gun-metal, the thickness of the lining should be = one-fourth that of the strap. White-metal makes a good lining for eccentric-straps.

The distance-piece between the lugs of the strap should admit of removal without withdrawing the bolts.

Eccentric-straps when bolted together, should only be made tight enough to move round by their own weight.

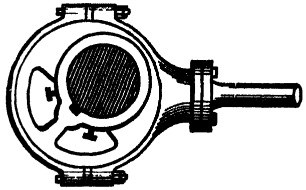


Fig. 49.—Eccentric and Strap.

Eccentric-Rod.—Diameter at slide-valve spindle-end = diameter of slide-valve spindle.

Diameter at eccentric-strap end = diameter of slide-valve spindle multiplied by 1·3.

Feed-Pump, shown in Fig. 50.—The diameter of the ram may in most cases be = $\frac{1}{8}$ diameter of cylinder when $\frac{1}{2}$ stroke of piston; and $\frac{1}{6}$ diameter of cylinder when $\frac{1}{4}$ stroke of piston.

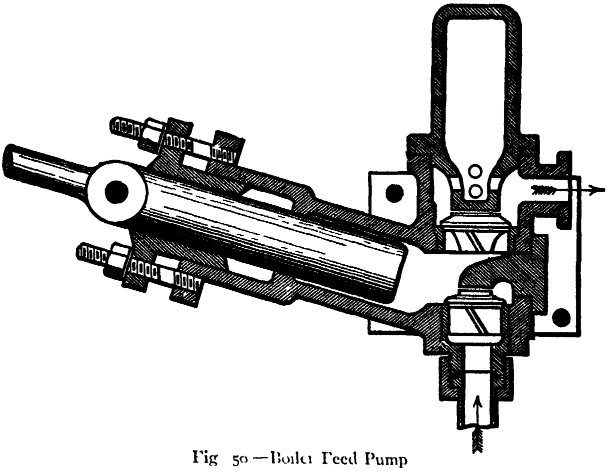


Fig 50—Boiler Feed Pump

The wings of the suction and delivery valves should be placed at an angle, as shown in the engraving, so that when the valve lifts, the water will cause it to partly rotate and change its position on the seat at each beat, in order to prevent attachment of grit, and induce uniform wear of the faces of the valve and seat. Rules and data for pumps are given in Section II.

A Wrought-iron Cross-Head, of the form shown in Fig. 51, has jaws cut out of the solid and is fitted with four slide-bars.

Diameter of recessed part of boss A = diameter of piston-rod multiplied by 1·75.

Length of recessed part of boss A = diameter of piston-rod multiplied by 1·2.

Diameter of collar at end of boss B = diameter of piston-rod multiplied by 2.

Width of collar at end of boss B = diameter of piston-rod multiplied by ·42.

Thickness of fork at the boss C = diameter of piston-rod multiplied by ·6.

Thickness of fork below the boss D = diameter of piston-rod multiplied by ·42.

Diameter of the boss of the fork C = diameter of cross-head pin multiplied by 2.

Diameter of cross-head pin E = diameter of crank-pin multiplied by ·75.

Width of fork F = diameter of cross-head pin multiplied by 1·2.

Length of cotter-hole in boss = diameter of piston-rod multiplied by ·8.

Width of cotter-hole = diameter of piston-rod multiplied by ·22.

The edges of the cotter should be circular.

Diameter of the slideblock-pin = diameter of crosshead-pin multiplied by ·75.

Taper of hole in crosshead for piston-rod = $\frac{1}{4}$ of an inch per foot.

Slide-Block.—Width of sliding-surface of the slide-block of the cross-head, shown in Fig. 51, = diameter of piston-rod for wrought-iron slide-bars; and = diameter of piston-rod multiplied by 1·4 when the slidebars are of cast-iron.

Thickness of slideblock = diameter of slideblock-pin multiplied by 1·8.

Length of sliding surface of the slide-block = width of sliding surface multiplied by 3 to 4.

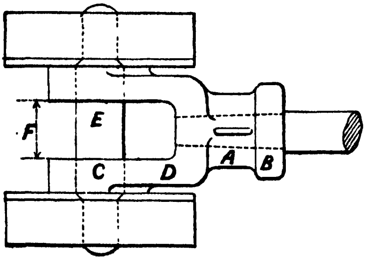


Fig. 51.—Cross-head.

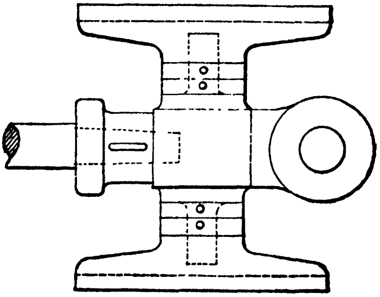


Fig. 52.—Cross-head.

A Wrought-Iron Cross-head, of the form shown in Fig. 52, has 2 slidebars, arranged one above and one below the cross-head, the slide-blocks being adjustable by lock-nuts on the slide-block-pin.

Width of the sliding surface of the slide-block = diameter of piston-rod multiplied by 2.

Length of sliding surface of slide-block = width of sliding surface multiplied by 4. The vibrating action of the connecting-rod tends to rock the cross-head on its bearings. The tendency to rock practically ceases when the length of the slide-block is equal to two-thirds the length of the stroke.

From centre of the slide-block-pin to the centre of the cross-head-pin = diameter of cross-head-pin multiplied by 2·5. From centre of the slide-block-pin to the outside of the collar on the end of the boss of cross-head = diameter of cross-head-pin multiplied by 2·5. The proportions of the fork and cross-head-pin may be found by the same rules as the other cross-head given above.

Strips of white-metal are in some cases let into the bearing surfaces of slide-blocks in order to reduce friction.

A Steel Cross-Head for two slide-bars of another design is shown in Figs. 53 and 54. The slide-blocks are V-shaped, adjustable by cotters with screw-ends and nuts.

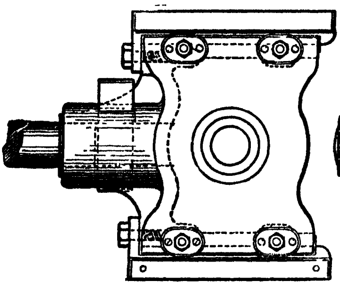


Fig. 53.—Steel cross-head.

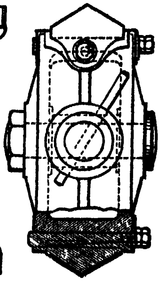


Fig. 54.

Slide-Bars of the form shown in Fig. 55 admit of ready adjustment. The bars are four in number, two being placed on each side of the cross-head.

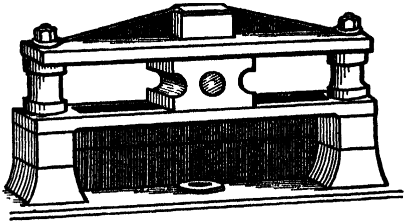


Fig. 55.—Slide-Bars.

Slide-bars, width = to diameter of piston-rod when wrought-iron; and when cast-iron, width = to diameter of piston-rod multiplied by 1·4.

Thickness = to width multiplied by ·6 for wrought-iron, and by ·4 for cast-iron when made with a rib in the centre.

Depth of rib = width of bar multiplied by ·7.

Thickness of rib = ½ of the depth of the rib.

Diameter of bolts for slide-bar = width of slide-bar multiplied by ·4.

Slide-Bars, 2 in number, arranged 1 above and 1 below the cross-head.

Width = diameter of piston-rod multiplied by 2.

The slide-bars should be recessed at each end, to prevent a ridge forming, due to wear, which would cause a knock or thump at each end of the stroke.

The Connecting-rod with strap-end, shown in Fig. 56,

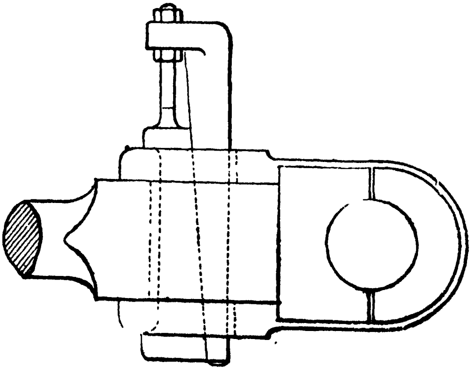


Fig. 56.—Connecting Rod with strap-end.

is fitted with gun-metal bushes adjustable by a cotter attached to a screw on the end of the gib.

Thickness of strap at the end = diameter of bearing multiplied by ·33.

Thickness of strap at the side = diameter of bearing multiplied by ·24.

Thickness of strap at cotter-hole = diameter of bearing multiplied by ·4.

Width of strap = length of bearing multiplied by ·7.

Length of strap beyond the cotter-hole = diameter of bearing multiplied by ·54.

Distance from end of gun-metal bush to edge of cotter = diameter of bearing multiplied by ·54.

Thickness of gun-metal bush at the end = diameter of bearing multiplied by ·25.

Thickness of gun-metal bush at the side = thickness of gun-metal bush at the end multiplied by ·75.

The bushes should be carefully adjusted to the crank-pin. Play in the bushes tends to wear the crank-pin oval, and excessive play causes a knock at each end of the stroke.

Width of gib and cotter at the centre = the diameter of the bearing.

Thickness of gib and cotter = diameter of bearing multiplied by ·22.

Taper of cotter, $\frac{1}{2}$ inch per foot.

Depth and width of the clip of the gib, each = the thickness of the gib.

Diameter of the connecting-rod at the small end = the diameter of the piston-rod.

Diameter of connecting-rod at the end next to the crank, or the large end = the diameter of the piston-rod multiplied by 1·25.

Diameter of connecting-rod at the centre = the diameter of large end plus $\frac{1}{16}$ of an inch per foot of length of the rod.

The diameter of the smallest part of the rod should not be less, when of wrought-iron, than = diameter of cylinder in inches × ·018 × square root of the initial pressure of the steam in lbs. per square inch.

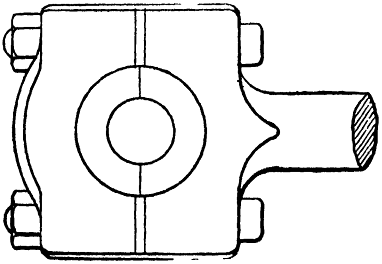


Fig. 57.—Connecting-Rod with Cap-End.

Length of connecting-rod = twice the length of the stroke.

The bending action is considered to be greatest at a point equal ·6 of the length of the rod, measured from the cross-head-end of the rod.

The Connecting-rod with Cap-end, shown in Fig. 57, has bushes adjustable by bolts.

Cap-bolts.—The sectional area of each bolt should be equal to one-half the sectional area of the piston-rod.

Thickness of cap = diameter of bearing multiplied by ·5.

Width of cap and rod-end = length of bearing multiplied by ·7.

Thickness of gun-metal bush = diameter of bearing multiplied by ·2,

The Connecting-rod with Cap-end, shown in Fig. 58, is of very strong construction. The cap hooks over projections on the jaws, turned concentrically with the rod: the bushes are flanged on both sides; the wear of the bushes is taken up by a wedge, adjustable by screws. An end view of the connecting-rod is shown in Fig. 59.

Cap-Bolts.—The sectional area of each cap bolt to be at least equal to one-fourth the sectional area of the piston rod.

Thickness of gun-metal bush at the end = diameter of bearing multiplied by ·25.

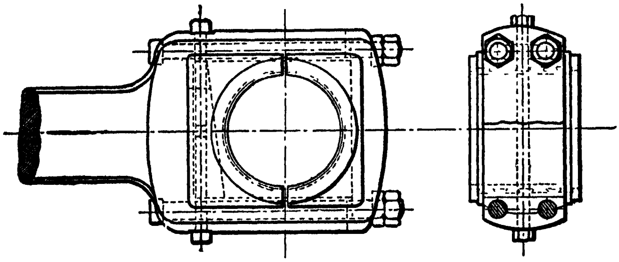


Fig 58. Fig. 59.
Connecting Rod with Cap-end.

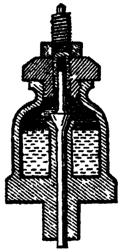


Fig. 60.—Lubricator for Connecting-Rod.

Thickness of gun-metal bush at the side = diameter of bearing multiplied by ·2.

All the above proportions are for connecting-rods of wrought-iron. The proportions of connecting-rods of steel may, in a general way, be 20 per cent. less than those for wrought-iron.

A Lubricator for the large end of a Connecting-Rod is shown in Fig. 60. It is fitted with a valve having a spindle resting on the crank-pin. The motion of the crank causes the valve to rise and fall, and the oil is delivered on the journal drop by drop. The lift of the valve is regulated by a screw.

Engine-bed when made Box-pattern, like the section of bed shown in Fig. 61.

Full width across the top = diameter of cylinder multiplied by 2.

Width of each side frame or box = diameter of cylinder multiplied by ·5.

Width inside the two frames = diameter of the cylinder.

Thickness of metal = thickness of metal of the cylinder multiplied by ·7.

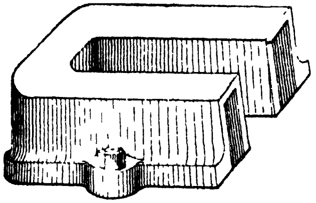


Fig. 61.—Section of Engine-Bed.

Depth of bed = diameter of cylinder multiplied by ·5 to ·6.

To Adjust an Engine-Bed, or to steady a slack corner of the bed:—Wedge the bed level, lute the bottom of the bed with clay at the defective part, and run in expansive-metal between the bed and the foundation-stone. A good expansive-metal for this purpose consists of lead, 9 parts; antimony, 2 parts; bismuth, 1 part.

Vertical Compound Engine.—A two-crank compound engine is illustrated in Fig. 62. A special feature of the engine and one which contributes largely to its simplicity is the arrangement of slide valves. One eccentric, rod and valve only being used to carry the H.P. and L.P. slide valves. The high pressure slide valve is superposed above the low pressure, working in the same valve chamber, the high-pressure valve taking steam on the inside and exhausting directly to the low pressure, which cuts off on the outside edge. The high pressure slide valve is arranged to give a variable cut-off to meet occasional variations in load and change from condensing to non-condensing with improved economy.

Fly-wheel.—A fly-wheel temporarily absorbs, keeps, and equalizes power, and conduces to uniformity of motion. It stores up surplus energy of motion during the temporary development of excess of power by the engine, and gives it up again during a decrease of the driving-power. It therefore tends to neutralize variations in the motion of the crank-shaft, due to increase and decrease of power, and it consequently steadies the speed of the engine. The weight of a fly-wheel should be sufficient to permit the crank to pass its dead-centres without sensible diminution of speed.

The diameter of a fly-wheel is generally = the length of the stroke of the engine multiplied by $3\frac{1}{2}$ to 4.

The arms of fly-wheels present the least resistance to the air when of oval-section.

The weight of a fly-wheel, in cwts., is generally = the nominal horse-power of the engine multiplied by 3.

The weight of the Fly-wheel of a Steam-engine of a given indicated Horse-power may be found by this rule:—

Multiply the constant number 7,000,000 by the indicated horse-power to be developed by the engine, and divide by the product of the square of the radius of the fly-wheel in feet by the cube of the number of revolutions per minute, the quotient will be the weight of the fly-wheel in cwts.

Example.—A fly-wheel of 10 feet diameter making 56 revolutions per minute is required for a steam engine of 40 indicated horse-power. Required the weight of the wheel in cwts.?

$$\text{Then } \frac{7000000 \times 40 \text{ indicated horse-power}}{(5 \text{ ft. radius of wheel})^2 \times (56 \text{ revolutons})^3} = \frac{7000000 \times 40}{25 \times 175616} = 64 \text{ cwts.}$$

the weight of fly-wheel required for that engine.

This rule gives the weight of the fly-wheel complete, that is, including the boss, arms, and rim. The weight of the arms and boss together is generally equal to about one-third the weight of the wheel, and the weight of the rim equals about two-thirds the weight of the wheel.

Maximum velocity of Fly-wheels.—The maximum safe velocity for good cast-iron is 80 feet per second. The wheel in the previous example is 10 feet × 3·1416 = 31·416 feet circumference, and as it makes 56 revolutions per minute, the velocity of the circumference of the rim is—

$\frac{31.416 \text{ feet} \times 56 \text{ revolutions}}{60 \text{ seconds}} = 29.32$, or say 30 feet per second, or a little more than one-third the velocity at which it is safe to run a fly-wheel

Strength of Fly-wheels.—Centrifugal force is the inertia of matter, or

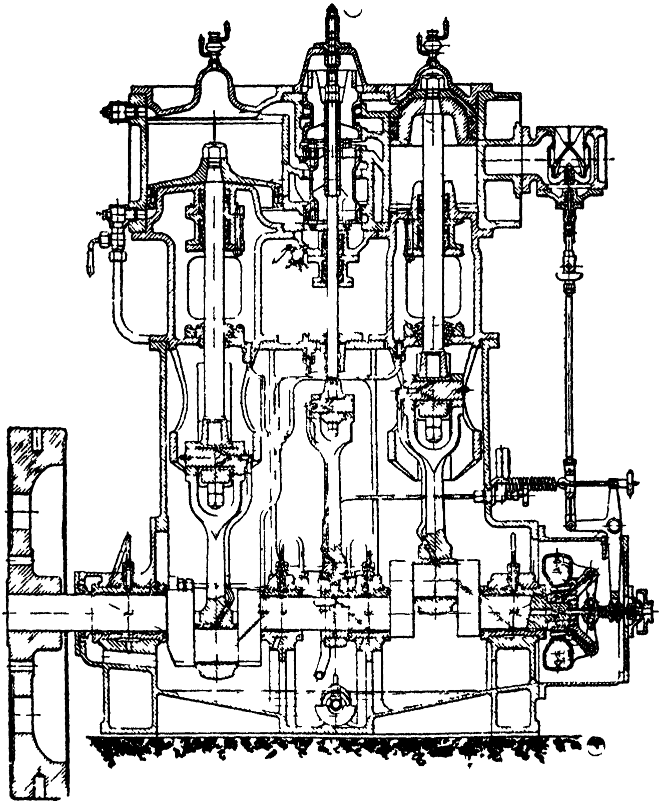


Fig 6[illegible]—Section of Belliss Patent Compound Self Lubricating Engine.

the resistance which matter always opposes to a force exerted to put it in motion from a state of rest Unhindered motion is always in a straight or direct line A moving body must move in a direct line, unless some force is exerted upon it to change the direction of its motion Each particle of matter in the rim of a wheel in motion, if the bond that holds it to the centre were broken, would move on in a straight line, in the direction it was moving at that instant, and all these straight lines would be tangents to the circle, as the water flying from the face of a grindstone perfectly illustrates But while this bond holds, each particle is being continually deflected from a direct line of motion, and compelled to travel in a circle. At every point in its path it is moved directly towards the centre around which it is revolving. This second motion is exactly at right angles with the direction in which its momentum would carry it if it were free. The latter is tangential, and the former is radial. The force drawing the body towards the centre acts upon it precisely as if it were at rest, because it is exerted at right angles with its line of motion at that instant. The body resists this deflection precisely as a body at rest resists being put in motion, and that resistance is what is called centrifugal force. It varies with different rates of deflection, according to the law of inertia, namely, directly as the square of the velocity imparted to the body in moving through a given distance towards the centre. The application of this law causes the force required to produce the deflection to vary directly as the diameter of the circle at a given rate of revolution, and as the square of the speed in any given circle. Centrifugal force may then be properly defined in either of two ways, namely, as the tendency of a body at rest to continue in that state, or as the tendency of a moving body to move in a direct line. The mode of computing the force required to produce this deflection from a direct line of motion in revolving bodies is as follows:—

The resistance to deflection from a direct line of motion that is offered by a body making one revolution in a minute, in a circle of 1 ft. radius, is ·000341 of its own weight. And this resistance varies directly as the radius of the circle, and as the square of the number of revolutions per minute. Thus let

$A =$ the *radius* of a wheel in feet;
$R =$ the revolutions per minute;
$C =$ the constant ·000341;

then $A \times R^2 \times C =$ the centrifugal force of this wheel, in terms of its weight.

Example: Required the centrifugal force of a wheel 20ft. in diameter, the rim of which weighs 10,000 lbs. at 100 revolutions per minute? Then, $10 \times 100^2 \times {\cdot}000341 \times 10{,}000$ lbs. $= 341{,}000$lbs. This is the sum of all the centrifugal strains in the rim of this wheel. In these computations the arms and boss are omitted, as their strength is always in excess of their centrifugal strains. The only factors considered are the centrifugal force of the rim, and its cohesive strength. The radius of the wheel should be measured to the centre of the cross-section of the rim. This force is exerted to burst a wheel of uniform section, in the same manner precisely in which the force of steam is exerted to burst a cylindrical boiler, that is, equally in all directions, and it is resisted in the rim of the wheel precisely as the latter is resisted in the shell of the boiler, therefore the computation for the strength required in the rim or in the shell is made on the same principle.

The strain to be resisted by the cross-sections of the rim may be formed by this *Rule:* Divide the sum of all the strains, ascertained as above, by the ratio of the circumference to the diameter of the wheel—that is, by 3·1416—and the quotient will be the amount of the strain that will have to be resisted by the combined strength of any two opposite cross-sections of the rim of the wheel.

Taking for example the data from the previous example—Then 341000 lbs.÷3·1416=108,540lbs. the strains to be resisted by or in any two opposite cross-sections. A rim of this weight and diameter would probably have about 50 square inches in its cross-section area, or 100 square inches in the opposite areas. So the strain will be 1,085 lbs. on each square inch. Taking the strength of the rim at 10,000 lbs. per square inch, the factor of safety in this case will be a little over 9. Good cast-iron has a greater tensile strength than this, but in the case of heavy masses like fly-wheel rims, the metal in which has not been decarbonised at all by remelting, it is not safe to assume in any case a greater tensile strength than 10,000lbs. This wheel could be run, however, at 200 revolutions, and still on this basis would have a factor of safety of 2¼. The difficulty with large fly-wheels, however, is rarely or never on account of insufficient strength of their cross-section. The weakest part is generally the joints of the wheel, when made in segments. The segments are united by connections which are frequently weak relatively to the strength of the rim, and every wheel is as strong as its weakest place, and no stronger. In most cases two tons, or 4,480 pounds per square inch, is the greatest tensile stress that should be allowed on cast-iron. This rule may be explained as follows:—

In Fig. 63 let the circle A B C D represent the rim of a fly-wheel revolving about its centre E. At F the rim tends to move in the tangent F G, but it is compelled instead to follow the arc F B. It is deflected in the direction of the radius F E, and its resistance is necessarily in the opposite direction E F. The strain thus produced is, however, not in fact exerted on the line FE, because there is, by previous supposition, no metal there; but all these strains are transferred to or received in the rim itself. To understand how this is done, let the circle be bisected in any two directions at right angles with each other, as by the lines A C and B D. Now, every force, in whatever radial direction it is exerted, may be resolved into two forces at right angles with each other, and perpendicular to these two lines; and if the radius represents the amount of the force, then these two perpendiculars will represent the two rectangular components of it. Thus F L and F H are

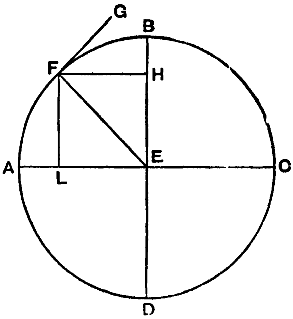


Fig. 63.—Diagram of Strains in a Fly-Wheel.

thus rectangular components of the force F E, and represent the equivalent strains in these two directions. But F L is the sine of the angle A E F, and F H is equal to L E, the cosine of the same angle. And so, universally, the sines of all the angles in the circle represent the strains in the rim which are pependicular to the line A C, and the cosines represent those which are perpendicular to the line B D, and these together are equivalent to the sum of all the radial strains. The sum of each of these two components will then be less than the sum of all the centrifugal strains in the rim, as the average of all the sines, or of all the cosines, which is the same thing, is less than the radius. The average sine or cosine, ·63662, has the same relation to the radius that the latter has to the quadrant of the circumference, or that 1· has to 1·5708. So, to get the sum of all the strains exerted in the two directions perpendicular to the line A C, the sum of all the radial strains must be divided by 1·5708, and those exerted in the two directions perpendicular to the line B D will be the same. But this gives the sum of the strains at these points of the rim in both directions, and of this one-half constitutes the resistance against which the other half is exerted. The bursting strain to be resisted at any two opposite points of the rim is therefore, as already given, the sum of all the radial strains divided by 3·1416.

HIGH-PRESSURE CONDENSING STEAM-ENGINES.

Condenser.—The object of a condenser is to remove the pressure of the atmosphere which opposes the advance of the piston in the cylinder, so that all the work performed by the steam may be brought to bear effectually upon the piston. The steam in a condenser is condensed instantaneously by the cooling medium.

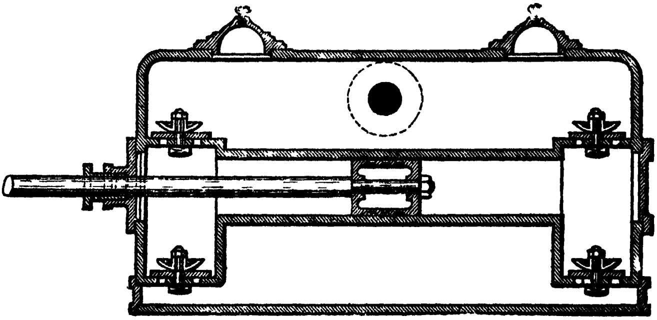


Fig. 64.—Sectional Elevation of Condenser and Air-Pump.

The jet-condenser shown in Fig. 66 is of the multi-jet type, comprising a cast-iron condenser fitted with specially shaped nozzles for spraying the injection water into the condenser, a " Hivac " steam ejector for extracting the air and an extraction pump of centrifugal type capable of withdrawing the whole of the cooling water and condensed steam and discharging same against a given lead. This arrangement is manufactured by Messrs. Hick, Hargraves, Bolton.

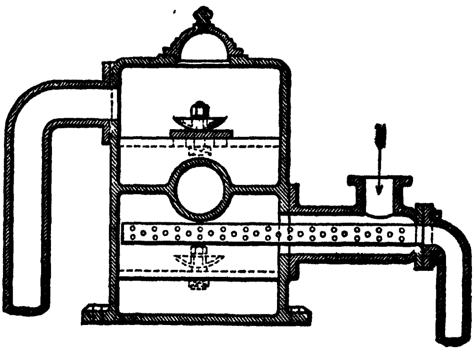


Fig. 65.—Sectional End-View of Condenser and Air-Pump.

Jet-Condensers are frequently employed for Stationary Condensing-Engines. A jet condenser with horizontal air-pump and hot-well combined in one casting is shown in sectional elevation in Fig. 64; and in sectional end-view in Fig. 65. The exhaust-steam from the engine enters the condensing-chamber where it is immediately condensed by a spray of water from a rose on the end of the injection-pipe. The condensed steam and condensing-water is pumped out of the condenser into the hot-well by the air-pump, which is double-acting. Part of the water from the hot-well is returned to the boiler as feed-water, and the remainder is discharged into a reservoir to be cooled. By condensing the exhaust-steam in this manner a partial vacuum is created behind the piston in the steam-cylinder and the back-pressure is diminished. The heat of the steam is imparted to the water, and with an ample supply of injection-water, the vacuum

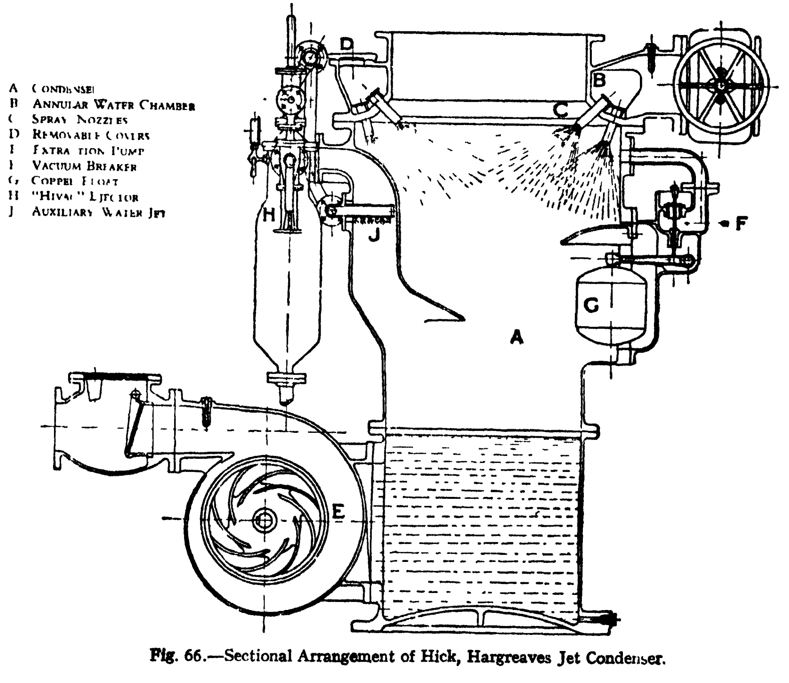


Fig. 66.—Sectional Arrangement of Hick, Hargreaves Jet Condenser.

would be practically perfect, if no air passed with the exhaust-steam to the condenser.

Capacity of a Jet Condenser.—The capacity of the condenser should not be less than the capacity of the air-pump, but rather greater. A good proportion is to make the cubic contents of the condenser equal to three-fourths that of the cylinder in communication with it.

Diameter of injection-pipe = diameter of the cylinder divided by 7.

Diameter of overflow-pipe from hot-well = diameter of cylinder × ·3

Diameter of cold-water pump = diameter of the cylinder multiplied by ·3, when its stroke equals ½ the stroke of engine.

Condensing-water for Jet-condensers.—The quantity of injection-water required per indicated horse-power of the engine, in cubic feet per minute is generally = temperature of the steam in degrees Fahr. multiplied by ·00304; approximately 6 gallons are required per indicated horse-power per minute. The quantity of injection-water required depends upon the temperature of the exhaust-steam and the temperature of the condensing-water. On an average, 3 gallons of injection-water are required per pound of steam consumed per hour by the engine. For instance, a steam-engine using 20 pounds of steam per indicated horse-power per hour requires 20 × 3 = 60 gallons of condensing-water per hour for each indicated horse-power developed by the engine. When the steam-consumption of an engine is not known, it may be assumed to be 23 pounds, and 23 pounds × 3 gallons = 69 gallons of injection-water should be provided per indicated horse-power per hour, which is probably the average maximum quantity of condensing-water used by stationary condensing steam-engines. The temperature of the hot-well should be not less than 100° Fahr.

Reservoirs for Cooling Condensation-Water flowing from the hot-well of condensing steam-engines should equal in capacity 130 gallons of water per indicated horse-power per hour. The area of the surface of the water should equal 75 square feet per indicated horse-power for an engine working 12 hours per day, or equal 150 square feet if working 24 hours, or day and night.

Vacuum in the Condenser.—The vacuum is generally estimated by inches of mercury, each pound of vacuum representing 2 inches of mercury, therefore each inch of mercury represents a diminution of ½ a lb. in the back-pressure, and a gain of an equivalent amount of effective pressure on the piston of a steam-engine. The vacuum is never perfect in the condenser, owing to the presence of a small quantity of air and vapour, which is generally equal to a pressure of from 2 to 3 lbs. per square inch. This vapour-pressure forms a back-pressure which resists the movement of the low-pressure piston. If there were a vacuum of 24 inches in the condenser, the back-pressure would be reduced to the extent of 12 lbs., and the advance of the piston would be opposed by a back-pressure of 15—12 = 3 lbs. per square inch, instead of 15 pounds per square inch, the pressure of the atmosphere. The vacuum depends upon the temperature of the condenser. A fall of vacuum in a cool condenser indicates defects in the air-pump; and in a hot condenser it indicates a defective supply of condensing-water.

Imperfect Vacuum in a condenser may be caused by excessive clearance spaces in the air-pump, in which vapour will remain and expand, and other defects in the design of an air-pump: and also by contracted exhaust-passages in the cylinder. A bad vacuum may be caused by a deficient supply of cooling water, and by the presence in the condenser of air, drawn into the cylinder through imperfectly packed glands of piston-rods, valve-spindles and drain-cocks, or through defective joints, and fractures or blow-holes in castings. It may be caused by hot-water carried with the steam from the cylinder to the condenser as the result of boiler-priming.

Surface-Condensers.—Steam is condensed in surface condensers by contact with the cold surfaces of a number of small metal-tubes, without its coming in contact with water. The tubes are cooled by water supplied by a circulating pump. A cooling surface of from 2 to 2½ square feet is usually provided per indicated horse-power of the engine. The quantity of cooling water provided for each pound of steam to be condensed is usually from 50 to 60 lbs.

Air-Pumps.—The function of an air-pump is to remove the air and condensation-water from the condenser. The power required to work an air-pump, when the plunger is connected to the tail-rod of the piston of the engine as shown in Fig. 69, is equivalent to an additional back-pressure on the piston of the steam-cylinder of from ¾ of a lb. to 1 lb. per square inch. The valves of the air-pump are either of metal, india-rubber, or vulcanised fibre. The bucket, plunger or piston, piston-rings, grids, and bolts are of gun-metal.

The cubic contents, or the area × the length, of a double-acting air-pump should equal one-twelfth the cubic contents of the cylinder.

The diameter of a double-acting air-pump, of the form shown in Figs. 64 and 65, when the length of stroke is equal to one-half that of the engine, may be = diameter of cylinder multiplied by ·3.

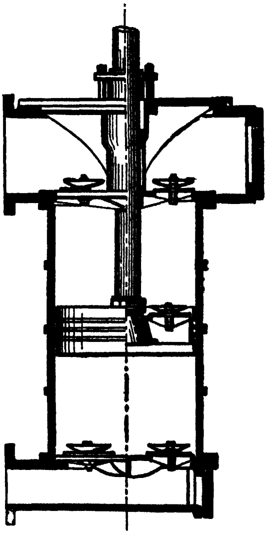


Fig. 67.—Vertical Single-Acting Air Pump.

A vertical single-acting air-pump, shown in Fig. 67, is the most efficient form of air-pump. The clearance between the bucket and the foot-valve should be as small as practicable.

The cubic contents of a single-acting air-pump should equal one-sixth the cubic contents of the cylinder.

The diameter of a single-acting air-pump, having a length of stroke equal to one-half that of the engine, may be = diameter of the cylinder multiplied by ·6.

Width of air-pump piston or plunger = diameter of air-pump multiplied by ·3 to ·7 according to the description of packing-rings used. Packing-rings are frequently dispensed with, in which case the width of the plunger is generally from one-third to one-half the diameter of the air-pump.

Diameter of air-pump rod = diameter of air-pump divided by 8.

The pump-rod should be of iron, cased with brass.

Metallic-packing is the best packing for the air-pump-rod, as it considerably reduces friction, requires little attention, and is least liable to admit air.

The area of delivery and suction-valves should each be = diameter of air-pump multiplied by ·7. For a high speed of plunger, the valves should not be less in area than that of the pump.

In applying the rules for air-pumps and condensers to compound-engines, the diameter of the low-pressure cylinder is to be employed as the unit of measurement. For the discharge of pumps, see rule on page 98.

A disc-valve for an air-pump is shown in Fig. 68. The disc is either of vulcanised fibre or india-rubber. The guard and grid are of gun-metal.

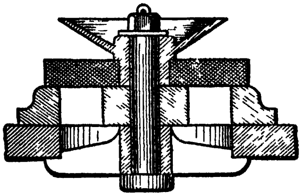


Fig. 68.—Valve for Air-Pump.

Air-pumps work very well without foot-valves when there is an ample supply of sufficiently cool injection-water.

Efficiency of Air-Pumps.—A vertical single-acting air-pump is capable of maintaining the highest vacuum in a condenser: a horizontal double-acting air-pump generally maintains the lowest vacuum.

The efficiency of single-acting vertical air-pumps averages 52 per cent., and that of double-acting vertical air-pumps 40 per cent. of the theoretical efficiency. The efficiency of horizontal single-acting air-pumps averages 40 per cent., and that of horizontal double-acting air-pumps averages 33 per cent.

Speed of Air-Pumps.—The low efficiency of air-pumps is frequently due to the speed of the plunger being so high that the water cannot follow it in a continuous volume, and a space is formed between the water and the plunger, in which air accumulates and impairs the action of the pump. A low speed of the bucket or plunger of an air-pump conduces to the maintenance of a good vacuum in the condenser. To obtain a high efficiency, the speed of the plunger should not exceed 100 feet per minute and to obtain a moderate efficiency, the speed should not be greater than 200 feet per minute. At speeds of from 300 to 400 feet per minute, the efficiency must necessarily be low.

Horizontal High-Pressure Condensing Steam-Engine.—A hori-

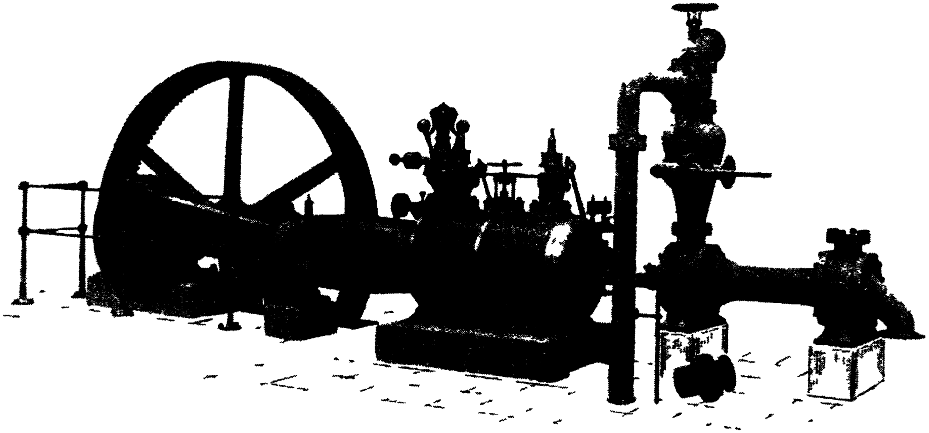


Fig 69 —Horizontal Single Cylinder Condensing Engine (Messrs Marshall, Sons & Co , Gainsborough)

zontal single-cylinder condensing steam-engine of simple construction, having all working parts easy of access, and fitted with the Marshall patent trip gear. The air pump working in conjunction with a jet-condenser is driven from the tail end of the piston rod. Particulars of this type of engine are given in the following table:

Table 5.—SIZES OF HORIZONTAL SINGLE-CYLINDER CONDENSING ENGINES, AS SHOWN IN FIG. 69.

SIZE OF ENGINE			NON CONDENSING				CONDENSING			
			Effective H P. at Boiler Pressure				Effective H P at Boiler Pressure			
Dia.	Stroke	R.P M.	120 lbs /sq. in.		150 lbs./sq. in.		120 lbs./sq. in.		150 lbs /sq. in.	
			Econ.	Max.	Econ.	Max.	Econ.	Max.	Econ.	Max.
7"	20"	135	19	32	21	35	17	33	19	37
8"	20"	135	24	41	27	46	22	44	24	49
9"	24"	125	34	58	38	65	31	62	34	68
10"	24"	125	43	72	47	80	38	76	42	85
11"	30"	110	57	96	63	106	51	101	55	112
12"	30"	110	67	114	75	126	60	120	66	133
13"	36"	100	87	147	96	162	77	154	84	171
14½"	36"	100	108	183	120	200	96	191	105	212
16"	42"	86	132	222	146	245	117	233	120	260
17"	42"	86	148	252	165	278	132	262	144	290
18"	42"	86	167	280	185	310	149	296	163	322
19"	42"	86	185	314	206	342	165	328	181	362
20"	48"	75	206	348	228	380	183	364	200	400
22"	48"	75	249	420	276	460	220	440	245	490

COMPOUND STEAM-ENGINES.

The Cylinder of a Steam-Engine is alternately exposed to a high temperature from the entering steam, and a low temperature from the exhaust-steam. If, for instance, steam enters a cylinder at a pressure of 70 lbs. per square inch, and leaves it at a pressure of 15 lbs. per square inch, the metal is exposed to a range of temperature of $303^\circ - 212^\circ = 91^\circ$ Fahr. resulting in considerable loss from condensation. By dividing the range of the temperature of the steam between two or more cylinders, greater uniformity of temperature is obtained in the cylinder and condensation is diminished.

The Steam in a Compound-Engine after performing part of its work by driving the piston in one cylinder, is exhausted into, and performs work

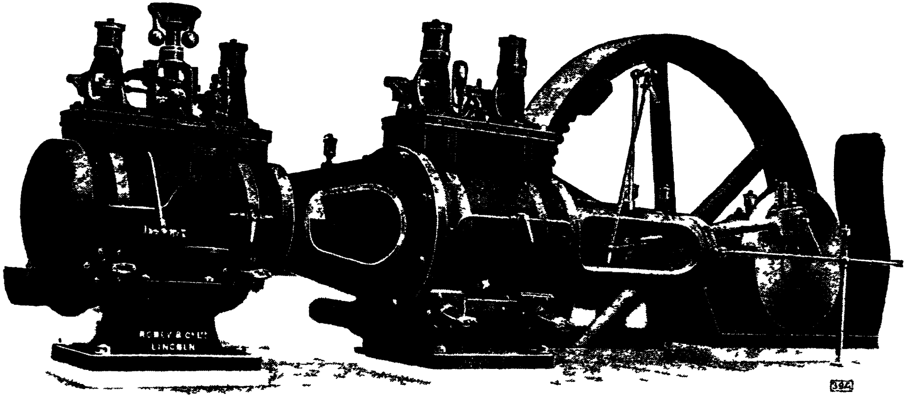


FIG. [illegible].—Tandem Compound Engine. (Messrs. Robey & Co.)

in, another cylinder, or in several cylinders in succession, before being discharged into the condenser to be condensed in a condensing-engine, or before being finally exhausted in a non-condensing-engine. By expanding the steam through a succession of cylinders the range of temperature in each cylinder is diminished, and the mean temperature in each cylinder is much nearer that of the initial temperature of the steam used in it, than is obtained in the cylinder of a simple engine, and the loss due to cooling is minimised.

The compound-engine permits the principle of expansion to be carried out to the fullest extent, that is, it enables steam to be used in the most economical manner, by employing its full expansive force; and it effects a considerable saving of fuel in comparison with a simple engine. The power developed by a compound-engine is theoretically the same as would be developed if the quantity of steam used by it were expanded in a single cylinder of the same capacity as the low-pressure cylinder. Hence, the area of the low-pressure cylinder of a compound steam-engine is calculated as if all the power were to be developed in that cylinder, which therefore requires to be of the same area as the cylinder of a simple engine of the same power. When separate pistons act upon separate cranks, the latter are placed at an angle of 90° apart on the same shaft in the case of double-expansion engines, and at equal angles of 120° apart in the case of treble-expansion engines, in order to obtain uniformity of rotative-pressure upon the cranks.

A Horizontal Tandem Compound Condensing Engine is illustrated in Fig. 70. This engine is compact and of strong construction and is manufactured by Messrs. Robey & Co., Lincoln, in various sizes up to about 1,000 H.P. The steam chest is formed on the top of the cylinders and is provided with machined chambers to receive the admission valves, these being connected direct with the working barrel. The cylinders are fitted with the Robey patent drop valve gear, the steam valves being of the circular double heat type. The seats are carried in an entirely separate casting which is held in place in the cylinder body by the dashpot, both the seats and the dashpot having copper rings for jointing.

To find the Area of the Low-pressure Cylinder of a compound, or double-expansion, steam-engine *Rule:* Multiply the number of horse-power the engine is required to indicate by 33,000, which will give the number of footpounds required per minute, divide this by the speed of the piston in feet per minute, and the result will be the total effective pressure on the piston at that speed to develop the given number of indicated horse-power; divide the quotient by the mean effective pressure per square inch on the piston, and the final quotient is the area in square inches of the low-pressure cylinder.

The speed of the piston in compound, or double-expansion, engines is usually not less than 420 feet per minute.

The ratio of expansion is found by dividing the initial absolute pressure of the steam in the high-pressure cylinder by the final pressure in the low-pressure cylinder.

The effective mean Pressure on the piston throughout the stroke is found by this *Rule:* To the hyperbolic logarithm of the total number of expansions add 1, then divide by the total number of expansions, and multiply the quotient by the initial absolute pressure of the steam (that is, the boiler pressure plus 15 lbs.) which will give the average pressure of the steam expanded the given number of times, from which deduct the back pressure, usually 3 lbs., and the result will be the mean effective pressure of the steam on the piston.

To find the Area of the High-pressure Cylinder of a compound, or double-expansion, steam-engine.—*Rule:* Multiply the initial absolute pressure of the steam in the high-pressure cylinder by ·042, with which result divide the area of the low-pressure cylinder, and the quotient will be the area of the high-pressure cylinder. In order to provide for the loss due to the fall in pressure of the steam in passing between the two cylinders, their areas found by the above rules should be increased to the extent of from 10 to 20 per cent.

The steam should be cut off in the high-pressure cylinder when the piston has moved ·45 of its length of stroke, and in the low-pressure cylinder at one-half the length of the stroke. The final pressure in the low-pressure cylinder should be from 8 to 9 lbs. per square inch in theory, but in practice it is from 2 to 3 lbs. more than that, and the lowest economical final pressure is from 10 to 12 lbs. per square inch.

Illustrations of these Rules.—Required the area of the cylinders of a compound, or double-expansion, steam-engine to indicate 100 horse-power: speed of piston 420 feet per minute: boiler pressure 86 lbs. per square inch.

Then, allowing 5 lbs. for loss of pressure between the boiler and the cylinder, the initial pressure in the high-pressure cylinder will be 81 lbs., and the initial absolute pressure 81 + 15 = 96 lbs. per square inch; and presuming the steam to be worked down to a final pressure of 12 lbs. per square inch it will give

$$\frac{96 \text{ initial absolute pressure in high-pressure cylinder}}{12 \text{ final pressure in low-pressure cylinder}} = 8, \text{ ratio of expansion.}$$

The hyperbolic logarithm of 8 is, from Table 2, $= 2{\cdot}0794 + 1 = \frac{3{\cdot}0794}{8} =$ $\cdot 3849 \times 96$ lbs. per square inch $= 36{\cdot}95$, the average pressure in lbs. per square inch of steam of 96 lbs. pressure expanded eight times, and if 3 lbs. be deducted for back pressure, it leaves 33·95 lbs. effective mean pressure per square inch; then

$$\frac{100 \text{ indicated horse-power required} \times 33{,}000}{420 \text{ speed of piston in feet per minute}} = 7857{\cdot}14 \text{ gross pressure on}$$

the piston at that speed; and $\frac{7857{\cdot}14}{33{\cdot}95 \text{ effective mean pressure}} = 231{\cdot}34$, the area in square inches of the large cylinder, and $96 \times {\cdot}042 = 4{\cdot}03$, and $\frac{231{\cdot}34}{4{\cdot}03} = 57{\cdot}4$ the area in square inches of the small cylinder. Then, if 20 per cent. be added to provide against loss by the pressure falling during the passage of the steam between the cylinders, the area of the low-pressure cylinder will be = 231·34 + 46·26 = 277·6 square inches, and the area of the high-pressure cylinder will be = 57·4 + 11·48 = 68·88 square inches, or $18\frac{3}{4}$ inches diameter for the large, and $9\frac{3}{8}$ inches diameter for the small cylinder, being a cylinder ratio of 4 to 1, which agrees with the best modern practice for that pressure of steam. If the initial absolute pressure of the steam had been 75 lbs. per square inch, the ratio of the areas of the cylinders would have been = 75 × ·042 = 3·15; and for a pressure of 60 lbs. per square inch, it would have been = 60 × ·042 = 2·52; and for an absolute pressure of 125 lbs. per square inch, it would have been = 125 × ·042 = 5·25.

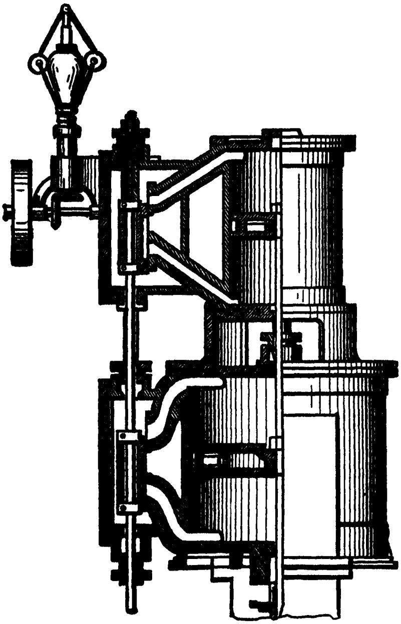


Fig. 71.—Section of the Cylinders of a Vertical-Tandem Compound Steam Engine.

The cylinders of a vertical tandem, compound, or double-expansion, condensing steam-engine, are shown partly in section in Fig. 71. The cylinders are inverted and placed over a crank-shaft fixed on a box-shaped foundation-plate. The governor is fixed on the cover of the steam-chest, and is driven by a belt from a pulley on the crank-shaft.

Triple-Expansion Engines expand steam in three stages, generally in three cylinders. A set of triple-expansion engines is shown in Fig. 72. The cylinders are arranged in a line over the centre-line of the crank-shaft. The power of each cylinder is transmitted to a separate crank, the cranks being placed at angles of 120° apart. The high-pressure cylinder is 29 inches diameter; the intermediate cylinder is 47 inches diameter, and the low-pressure cylinder is 76 inches diameter; the length of stroke being 51 inches. The air-pump is single-acting, of brass fixed in a cast-iron casing, it is $25\frac{1}{2}$ inches diameter; the bilge-pumps and feed-pumps are each $4\frac{1}{2}$ inches diameter; and the circulating-pump for the surface-condenser is 15 inches diameter. The diameter of the crank-shaft is $14\frac{1}{2}$ inches diameter. The high-pressure cylinder is fitted with a piston-valve 14 inches diameter: the other cylinders have slide-valves.

The Diameter of the Crank-shaft of Double, Triple, and Quadruple Expansion-Engines should not generally be less than that found by the following rule:—

$$\text{Diameter of crank-shaft in inches} = \sqrt[3]{\frac{PSD^2}{C}}$$

in which P = the absolute pressure of the steam in lbs. per square inch; S = length of stroke in inches; D = diameter of low-pressure cylinder in

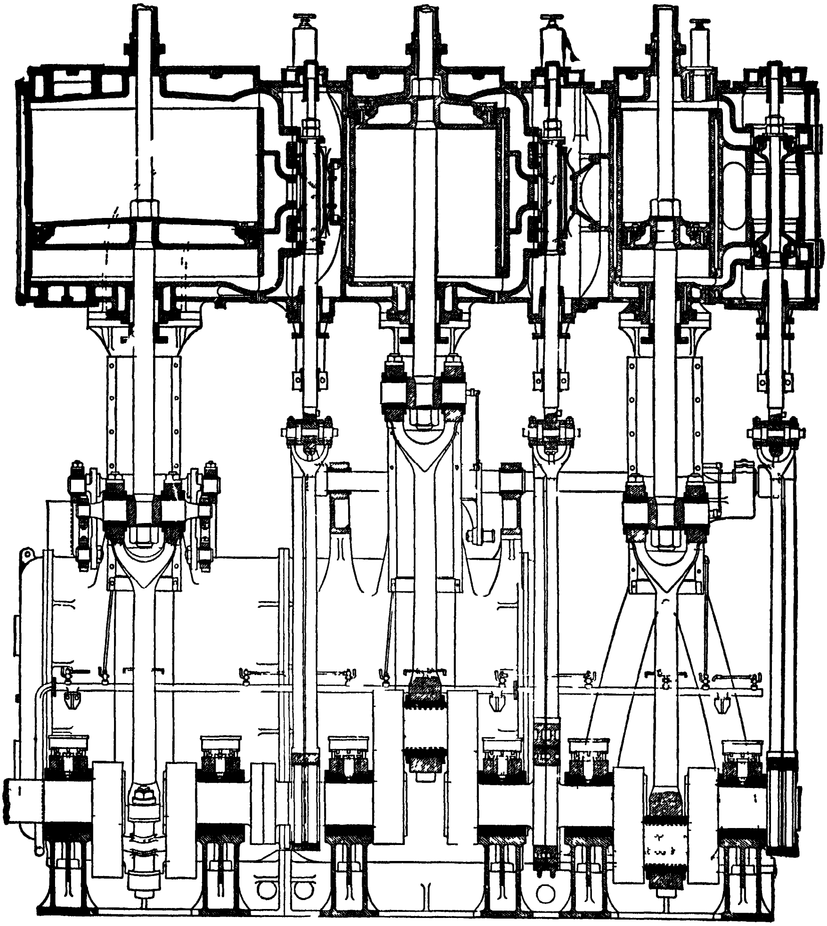


Fig 72.—Sectional Elevation of a set of Triple Expansion Engines

inches, C is a constant = 10,000 for double-expansion engines, 17,000 for triple-expansion engines, and 19,000 for quadruple-expansion engines

Friction of Crank-Shafts.—The friction of the crank-shaft of a steam-engine depends upon the load on the bearings, the finish and alignment of the rolling and bearing surfaces, the nature of the unguent employed, and the efficiency of the lubrication.

For crank-shafts making from 60 to 150 revolutions per minute, in true bearings efficiently lubricated with good oil, the resistance of friction due to a pressure of 1 lb. approximately averages as follows—

	Co-efficient of Friction
Wrought-iron crank-shaft working in bearings of hard gun-metal	·00178
Steel-crank-shaft working in bearings of hard gun-metal	·00172
Wrought-iron crank-shaft working in bearings of gun-metal, having strips of antifriction-metal let into the bearing surfaces . . .	·00124
Steel-crank-shaft working in bearings of gun-metal, having strips of antifriction-metal let into the bearing surfaces	·00120
Wrought-iron crank-shaft working in bearings of antifriction-metal of fine quality . . .	·00115

The friction increases slightly with the speed above 150 revolutions per minute. When the alignment of the crank-shaft is defective, either horizontally or vertically, it causes excessive friction, and may result in thumping and hot bearings.

LOCOMOTIVE-ENGINES.

The power of a Locomotive-Engine is determined by the tractive force it can exert upon the rails. The tractive force is the power which the pistons of the engine are capable of exerting through the driving-wheels to move the engine and train. The power a locomotive is capable of exerting with useful effect depends upon the adhesion or frictional hold of the driving-wheels upon the rails.

The Adhesive Power of a locomotive depends upon the weight on the driving-wheels, and is in ordinary weather about $\frac{1}{6}$ of the load on the driving-wheels; in goods engines the wheels are coupled, and the adhesive force is due to the weight resting on the coupled wheels. Hence, to prevent the wheels of a locomotive slipping on the rails, the weight resting on the driving-wheels must be about six times as great as the power exerted by the engine to slip the wheels.

Train-Resistances.—The power developed by a locomotive-engine is expended in overcoming the resistances due to wheel-friction, gradients, curves, and wind-pressure. Formulæ for the resistances on railways are as follows:—

Resistance of engine, tender, and train . $\Big\}$ $R = 8 + \frac{V^2}{171}$ | Resistance of train alone $\Big\}$ $R' = 6 + \frac{V^2}{240}$

R = total resistance of engine, tender and train in lbs per ton gross;

R′ = resistance of train alone in lbs. per ton; V = speed in miles per hour. These rules are for a straight line of rails; and one-half more is to be added for the resistance due to curves, imperfections of the road, and wind-pressure.

Table 6.—RESISTANCE OF TRAINS.

Speed in Miles per Hour.	5.	10.	15.	20.	30.	40.	50.	60.	70 miles.
Frictional Resistance in lbs. per Ton of Engine, Tender, and Train .	12·2	13	14	15·5	20	26	34	43·5	55 lbs.
Frictional Resistance in lbs. per Ton of the Train alone . .	9·15	9·6	10·5	11·4	14·6	19	24	31·5	36·6 lbs.

It requires a force of about 7 lbs. per ton, to keep waggons moving on a level line of rails, at a very slow speed after they are started.

The Tractive Power of a locomotive-engine is found by this *Rule:* Multiply the square of the diameter in inches of one cylinder, by the length of stroke in inches, and divide the product by the diameter in inches of the driving-wheel. The quotient will be the tractive force in pounds, for each pound of effective pressure per square inch on the piston; and this quotient multiplied by the effective mean pressure in the cylinder, will give the full tractive force in pounds exerted by the engine.

The Effective Mean-Pressure on the Pistons equivalent to a given tractive force at the rails may be found by this *Rule:* Multiply the diameter of the driving-wheel in inches by the total equivalent tractive force at the rails in pounds, and divide the product by the product of the square of the diameter of the cylinders in inches by the length of stroke in inches.

The Maximum Boiler-Pressure of locomotives is about 240 pounds per square inch. The standard working-pressure of the steam is 160 lbs. per square inch on some railways, and 140 lbs. per square inch on others; but the effective mean pressure is much less, owing to working the steam expansively. The maximum mean-pressure on the pistons under any circumstances does not generally exceed three-fourths of the boiler-pressure.

The Resistance in lbs. per ton of the train due to gravity, on an incline may be found by this *Rule:* Divide 2240 by the rate of the gradient.

To find the resistance in lbs. per ton due to the velocity of the engine, tender, and train. *Rule:* Square the speed of the train in miles per hour, and divide the result by 171, and add 8 to the quotient. To the sum, add 50 per cent. for resistance due to curves, imperfections of the road, and wind-pressure.

The Load the Engine can take, in tons, including the weight of the wagons, but not that of the engine and tender, may be found by this *Rule:* Add together the resistance due to gravity, and the resistance due to velocity, with which result divide the tractive force, and from the quotient subtract the weight of the engine and tender in tons.

These Rules may be illustrated by the following example: Required the load which a locomotive-engine with cylinders 17 inches diameter and 24 inches length of stroke, with a driving-wheel 5 feet diameter, will take on an incline of 1 in 70 at a speed of 20 miles per hour, boiler pressure 140 lbs. per square inch, weight of engine and tender 55 tons?

The tractive force which the engine is capable of exerting is $\frac{17^2 \times 24}{60} =$ $115{\cdot}6$ lbs. for each lb. of effective pressure per square inch on the pistons. The boiler-pressure of 140 lbs. per square inch gives $140 \times \frac{3}{4} = 105$ lbs. effective pressure, which multiplied by the tractive force in lbs. $= 105 \times 115{\cdot}6$ gives 12,138 lbs. as the total tractive force exerted by that engine.

The effective mean pressure on the pistons equivalent to that tractive force at the rails is $= \frac{5 \text{ feet} \times 12 \times 12138}{17 \times 17 \times 24} = 105$ lbs. per square inch.

The resistance due to gravity is $= \frac{2240}{70 \text{ gradient}} = 32$ lbs. per ton.

The resistance due to the velocity is $= \frac{20 \times 20}{171} + 8 = 10{\cdot}34$ lbs. and with 50 per cent. added, is equal to 15·51 lbs. per ton.

The load which the engine will take will be $= \frac{12138}{32 + 15{\cdot}51} - 55 = 200$ tons and taking 8 tons as the average gross weight of each wagon, the train would consist of $\frac{200}{8} = 25$ loaded wagons.

The total weight of the engine, tender and train is 255 tons, and the resistances due to velocity and gravity are $= 32 + 15{\cdot}51 = 47\ 51$lbs. per ton, or $= 255 \times 47{\cdot}51 = 12115$ lbs. for the train.

The train moves $\frac{20 \text{ m.} \times 1760 \text{ yds.} \times 3 \text{ ft.}}{60 \text{ minutes}} = 1760$ feet in one minute, and the power exerted by the engine is $= \frac{12115 \times 1760}{33000} = 646$ indicated horse-power.

The coal burnt per indicated horse-power would be at least $2\frac{1}{2}$ lbs. per hour, then $\frac{646 \times 2\frac{1}{2}}{20 \text{ miles}} = 80$ lbs. of coal per mile, or $80 \times 20 = 1600$ lbs. of coal burnt per hour.

The evaporation would be, say, 9 lbs. of water per lb. of coal, and it would require $\frac{1600 \times 9 \text{ lbs.}}{10 \text{ lbs. per gallon}} = 104$ gallons of water per hour.

The number of revolutions of the driving wheel would be $=$ $\frac{20 \times 1760 \times 3}{60 \times 5 \text{ feet} \times 3{\cdot}1416} = 112$ per minute; for each revolution of the wheel the piston moves twice the length of the stroke.

The speed of the piston would be 2 feet stroke × 2 × 112 revolutions = 448 feet per minute. *The total power* the above locomotive engine is capable of developing at that speed and pressure is=

$$\frac{17 \text{ diam. of cylinder} \times 17 \text{ diam. of cylinder} \times {\cdot}7854 \times 2 \text{ cylinders} \times 105 \text{ lbs. pressure} \times 448 \text{ ft. speed of piston}}{33{,}300} = 647 \text{ horse-power.}$$

The Consumption of Coal in Express Locomotive Engines is less than in slow-running engines. It averages $2\frac{1}{2}$ lbs. per indicated horse-power per hour in express-engines, and 3 lbs. per indicated horse-power per hour in goods-engines.

The Cylinders of a Locomotive Engine should be of best close grained cast-iron, as hard as it can be worked, and free from all defects. Two cylinders of equal diameter are invariably employed in locomotives, compound locomotives excepted. The diameter of the cylinders, shown in Fig. 73, may be found by the following formula :—

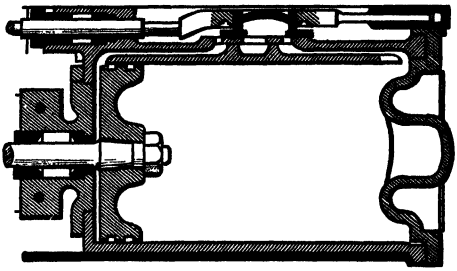


Fig. 73.—Cylinder of a Locomotive Engine.

Let W = the weight on the driving wheels in lbs.

C = a coefficient of adhesion per ton on the driving wheels, equal to 480 lbs. per ton, or = ·214, for passenger-engines, and equal to 448 lbs. per ton, or = ·2 for goods-engines.

D = the diameter of the driving wheels on the tread in inches.

P = the effective mean-pressure of the steam in the cylinder, which may be taken as equal, in a general way, to boiler-pressure × ·75.

S = the stroke of the piston in inches.

d = the diameter of each of the two cylinders in inches.

$$\text{Then, } d = \sqrt[2]{\left(\frac{W \times C \times D}{P \times S}\right)}$$

Example.—Required the diameter of the cylinders of a passenger locomotive-engine having a weight on the driving wheels of 27·9 tons : diameter of driving wheels 7 feet : boiler-pressure of steam 160 lbs. per square inch : length of stroke 26 inches.

$$\text{Then } d = \frac{27{\cdot}9 \text{ tons} \times 2240 \text{ lbs.} \times {\cdot}214 \times 84 \text{ inches}}{160 \text{ lbs. pressure} \times {\cdot}75 \times 26} = \sqrt[2]{361} = 19 \text{ inches,}$$

the diameter of each of the cylinders of that locomotive.

The Area of each Steam-Port should not be less than = the area of cylinder divided by 12·5, which is an average proportion.

The Length of the Steam-Ports should in no case be less than= diameter of cylinder in inches multiplied by ·83, but rather=diameter of cylinder in inches multiplied by ·9.

Width of Steam-Port = the area of the steam-port divided by the length of the steam-port.

The Area of the Exhaust Port should not be less than $\frac{1}{5}$ the area of the cylinder, which is a good proportion.

The Lap of the Slide-Valve is generally about = width of steam-port multiplied by ·73.

The Lead is frequently $\frac{1}{8}$ inch.

The Diameter of a Steel Piston-Rod should be=diameter of cylinder in inches multiplied by ·15.

The Speed of the Piston is from 400 to 1000 feet per minute, according to the class of engine.

The Width of Steel-Slide Bars may be = diameter of piston rod, multiplied by 1·13. The thickness of the middle part of steel-slide bars is generally equal to $\frac{3}{4}$ths the width of the bar.

The Area of the Sliding-Surface of the Slide-Block in square inches on each slide-bar should not be less than=diameter of cylinder in inches, multiplied by 2·2, when the blocks are of chilled cast-iron.

Metallic-Packing for the Piston-Rods of Locomotives.—The glands of the stuffing-boxes of the piston-rods and valve-spindles of locomotives using steam of very high pressure should be packed with metallic-packing. A simple and efficient form of metallic-packing for this purpose is shown in Figs. 74–75. It consists of a ring or sleeve of soft metal placed in an ordinary stuffing-box. The faces of the gland and bush are bevelled, at an angle of 45°, and the ends of the sleeve are coned to correspond. This packing is liable to leak slightly when first applied, but the leakage disappears after a few days working. A piece of ordinary round core-packing may be placed under the gland at the top of the metallic-packing, to give it a little elasticity and prevent the escape of any steam which may

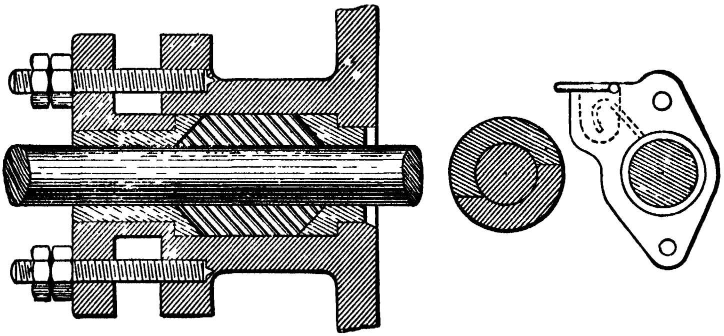


Fig. 74. Fig. 75.

Stuffing Box with Metallic Packing.

leak past the sleeve. The sleeve may either be solid or in halves arranged as shown in Fig. 73. The depth of the sleeve should not be less than = the diameter of the piston-rod in inches × 1·8, but rather = diameter of the piston-rod in inches × 2·25.

The mixture of metal of the metallic-packing consists of 76 per cent. of lead, 14 per cent. of tin, and 10 per cent. of antimony. It requires to be efficiently lubricated with good oil.

The Weight on the Driving Wheels of a locomotive-engine may be found by the following formula, in which the notation is the same as that in the previous formula:—

$$W = \frac{d^2 \times S \times P}{D \times C}$$

Example:—Required the weight on the driving wheels of the locomotive-engine described in the previous example.

Then $\frac{19 \times 19 \text{ inches} \times 26 \text{ inches} \times 160 \text{ lbs.} \times \cdot 75}{84 \text{ inches} \times \cdot 214} = 62496$ lbs. ÷ 2240 = 27·9 tons, the weight required on the driving-wheels of that locomotive-engine.

Power of Locomotive Engines.—From 30 to 40 per cent. of the indicated power developed by a locomotive engine is absorbed by the engine and tender, the remainder is the power available for pulling the train. The indicated horse-power developed is generally from 500 to 900 by locomotives of average size, and from 1000 to 1600 by locomotives of the largest size.

In some experiments with trains running over a distance of 50 miles on the Midland Railway, the mechanical horse-power, and the equivalent electrical power exerted, were as given in the following table:—

POWER DEVELOPED IN SOME EXPERIMENTS WITH LOCOMOTIVES AND TRAINS.

No.	Speed in Miles per hour.	Train Miles per hour.	Load including Engine, Tons.	Total Tractive Effort per train.	Mechanical Horse-Power per Train-hour.	Equivalent in K.W. hours.	Mechanical Horse-Power per hour.	Equivalent in K.W. per hour.
1	50	150	275	3575	477	356	1431	1068
2	32	64	300	2130	182	136	364	272
3	35	140	400	3160	295	220	1180	880
4	25	125	500	2750	183	137	915	685

No. 1 is an express passenger train; 2 is an ordinary passenger train with empty coaches; 3 is an express goods and perishables train; 4 is an ordinary goods and minerals train.

Tractive effort per ton $= 3 + \left(\frac{V^2}{250}\right)$, where V = speed in miles per hour.

$$\text{Horse-power} = \frac{\text{Tractive effort in pounds} \times \text{miles per hour.}}{375}$$

Tractive effort × load-tons = total tractive effort per train.

Single and Coupled Locomotives.—Coupled engines are generally used on lines with the heaviest gradients, and single engines for moderately heavy gradients and fast trains, although in some cases single engines are employed on heavy gradients. Single engines slip more than coupled engines. The slip of coupled engines, when the rails are not sanded, probably averages from 5 to 12 per cent., and of single engines from 8 to 16 per cent. That is, a single engine may make from 108 to 116 revolutions, where it should only make 100 revolutions. By the adoption of efficient steam-sanding apparatus, by which a fine spray of sand is blown under the treads of the wheels, the slip may be reduced to a minimum, and single engines are enabled to surmount heavy gradients with facility. Single engines generally cost less in repairs, run more freely, and are more economical in fuel than coupled engines. The adhesive power of driving wheels increases with the diameter, the larger the wheel the better the frictional hold on the rails. Bogies are of great advantage to locomotives running on curved lines.

The Locomotive illustrated in Fig. 76 is an express simple engine designed by one of the locomotive superintendents of the Great Western Railway.

It has four cylinders, each 14¼ inches diameter and 26 inches stroke.

The steam-ports are 25 inches long and 1¼ inches wide, and the exhaust ports are 25 inches long and 3 inches wide.

The boiler-barrel is 14 feet 10 inches long, and it varies in outside diameter from 4 feet 10¾ inches to 5 feet 6 inches.

The dimensions of the fire-box are 9 feet by 5 feet 9 inches, and 4 feet outside, and 8 feet $2\frac{7}{16}$ inches by 4 feet 9 inches, and 3 feet 2⅝ inches inside. The heights are 6 feet 6⅜ inches and 5 feet 0⅜ inches.

The centre-line of the boiler is 8 feet 6 inches from the top of the rail.

There are 250 tubes, each 2 inches diameter, and 15 feet $2\frac{5}{16}$ inches long.

The total heating-surface is 2142·91 square feet. The heating-surface of the tubes is 1988·65 square feet, and of the fire-box 154·26 square feet. The grate area is 27·07 square feet.

The four driving wheels of the engine are coupled. The bogie-wheels are 3 feet 2 inches diameter, the leading wheels are 6 feet 8½ inches diameter, the driving wheels are 6 feet 8½ inches diameter, and the trailing wheels are 4 feet 1½ inches diameter.

The working-pressure of the steam is 225 pounds per square inch.

The water-capacity of the tender is 3,500 gallons. The length over all of the engine and tender is 64 feet 1¾ inches.

The loaded weight of the engine is 74 tons 10 cwt., and of the tender 40 tons.

The total loaded weight of the engine and its tender is 114 tons 10 cwt. When empty, the engine weighs 69 tons 6 cwt., and the tender weighs 18 tons 5 cwt. The tractive effort is 26,560 pounds.

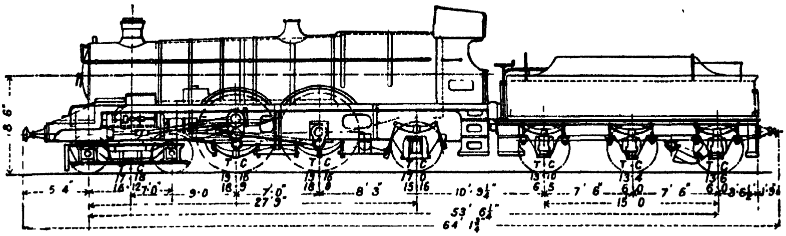


Fig. 76.—Four-Cylinder Express Locomotive of the Great Western Railway.

Compound Locomotive-Engines.—In using steam in a single cylinder with a slide-valve, as in ordinary locomotive-engines, it is not expedient to expand the steam more than from three to four times, and it is discharged into the atmosphere at a high temperature, and consequently before it has been deprived of all its available heat and power. The object of compounding locomotive-engines is to obtain a high efficiency in the use of steam, by carrying out the principle of expansion to the fullest extent, and extracting the greatest practicable amount of heat from the steam before it is exhausted. It permits of more than double the rate of expansion of steam possible in a simple engine, as an ordinary locomotive-engine, and the attainment of a more uniform pressure on the pistons throughout the stroke. The metal of a cylinder assumes the mean temperature of the steam passing through it, and as the temperature of the expanded steam falls below that of the metal, the steam absorbs heat from it before being exhausted, which is replaced from the entering steam. The heat thus abstracted from the high-pressure cylinder of a compound engine is utilised in the low-pressure cylinder. The steam lost in clearance-spaces, and leakage past the piston of the high-pressure cylinder, is also utilised in the low-pressure cylinder. The results of working compound locomotives show in some cases a gain of about 15 per cent. of tractive-power, and a saving of from 16 to 25 per cent. in fuel, and sometimes also a saving of 15 per cent. or more in water, over locomotives of similar construction with ordinary cylinders, or simple engines. The first cost, and the costs of repairs and maintenance of compound locomotive engines are, however, generally greater than those of simple locomotive engines.

Tests of Compound Locomotive Engines.—The results of some tests of compound locomotive engines are given in the table on page 74. In the tests of these and other locomotive engines, from 12 to 16 lbs. of water were evaporated per square foot of heating surface per hour. The evaporative efficiency was generally maximum where the power developed was least. Under conditions of maximum efficiency most of the boilers evaporated between 10 lbs. and 12 lbs. of water per lb. of dry coal. The efficiency falls as the rate of evaporation increases. When the power developed was greatest the water evaporated was from 6 lbs. to 8 lbs. per lb. of dry coal. The fire-box temperature was 1400-2300° Fahr.

A brick-arch in the fire-box increased the temperature of the furnace, and improved the combustion of the fuel-gases. The temperature of the smoke-box of all the boilers, when worked at light power, was about 500° Fahr. As the power was increased, it rose to from 600° Fahr. to 700° Fahr., according to the extent to which the boiler was forced. The minimum draught in the smoke-box was less than 1 inch of water, but it rapidly increased as the power increased, and the maximum draught was 8·86 inches of water.

Tests at High Speed of American Four Cylinder Balanced Compound Express Passenger Locomotives.

	Railway.		
	A.T. and S.F.	N.Y. Central.	Pennsylvania.
Wheel arrangement . . .	4—4—2	4—4—2	4—4—2
System of compounding (4 cylin.)	Vauclain.	Cole.	De Glehn.
Cylinders, high pressure . .	15 × 26	$15\frac{1}{2} \times 26$	$14\frac{3}{16} \times 25\frac{1}{4}$
Cylinders, low pressure . . .	25 × 26	26 × 26	$23\frac{11}{16} \times 25\frac{1}{4}$
Heating-surface	3237	3407	2656
Grate-area	$48\frac{1}{3}$	50	$33\frac{1}{3}$
Driving wheels	6ft. 7in.	6ft. 7in.	6ft. 8in.
Weight on drivers, lbs. . . .	99,200	110,000	87,850
Weight, total, lbs. . . .	201,500	200,000	164,000
Hours of test	1·50	1·50	1·24
Revolutions per minute . .	280	280·11	279·99
Miles per hour	65·77	65·69	66·96
Cut-off in high pressure cylinder	47·7	32·2	29·2
Boiler pressure, lbs. . . .	219·5	220	215
Branch-pipe pressure . . .	203·3	215·6	204·4
Draught in smoke box, ins. of water	5·58	4·77	3·27
Dry coal fired per hour, lbs. .	5,104	3,475	2,897
Dry steam used per hour, lbs. .	30,681	26,984	19,115
Water per lb. of dry coal, lbs. .	7·34	9·51	8·10
Indicated horse-power . . .	1459·7	1192·3	682·5
Dynamometer horse-power .	898	968·9	510·1
Frictional horse-power . . .	561·7	223·4	172·4
Draw-bar pull, lbs. . . .	5,120	5,530	2,857
Dry coal per I.H.P. hour, lbs. .	3·45	2·87	4·10
Dry coal per D.H.P. hour, lbs. .	5·60	3·53	5·48
Dry steam per I.H.P. hour, lbs. .	20·73	22·27	27·05
Dry steam per D.H.P. hour, lbs.	33·70	27·42	36·19
Efficiency of boiler . . .	47·27	61·81	51·48
Efficiency of locomotive . .	3·03	4·85	3·06

With reference to the grate-area, the results prove that the furnace-losses, due to excess of air, are not increased by increasing the grate-area. It appeared that the boilers for which the ratio of the grate-surface to the heating-surface was largest are those of greatest capacity.

Relatively large fire-box heating-surface appeared to give no advantage, either with reference to capacity or efficiency. The tube heating-surface appeared to be capable of absorbing the heat that was not taken up by the fire-box.

The maximum indicated horse-power per square foot of grate-surface was for the goods locomotive from 21·1 to 31·2, and for the passenger locomotive from 28·1 to 33·5.

The steam-consumption per indicated horse-power per hour necessarily depends upon the conditions of speed and cut-off. The average minimum for the simple goods locomotives was 23·7 lbs. The consumption when developing maximum power was 23·8 lbs, and when under conditions which proved to be the least efficient, 29 lbs. The compound locomotives consumed from 18·6 to 27 lbs. of saturated steam per indicated horse-power per hour. Aided by a superheater the minimum consumption was reduced to 16·6 lbs. of superheated steam per hour.

The coal consumption per dynamometer horse-power for the simple goods locomotive at low speeds was from 3·5 to 4·5 lbs.; at high speeds it increased to 5 lbs. The coal consumption of the compound goods locomotives at low speeds was from 2 to 3·7 lbs. The coal consumption of a two-cylinder compound locomotive at a high speed was from 3·2 to 3·6 lbs.

VALVE-GEAR FOR WORKING THE VALVES OF STEAM ENGINES.

MANY forms of valve-gear have been invented which actuate the valve from some moving part of the engine and dispense with eccentrics, of which the following are some of the most successful in practice:—

The Bryce-Douglas Radial Valve-Gear, shown in Fig. 77, was designed to reduce the length of inverted-cylinder-vertical engines, which, with this gear, is entirely governed by the length of bearing necessary for the crank-shaft, as it is possible to place the cylinders as closely together as they can go.

The leading feature of the gear is its adaptability for giving any desired distribution of steam. The cut-off can be made equal at both ends if desired, and the grade of expansion can be altered to any extent; the lead of the valves remains constant with any grade of expansion, and the cut-off-release, and compression can be made the same when the engines are going in either direction.

The lap and lead are given by the lever A working on the fulcrum P, one end of which is attached by a link B to the main cross-head C, the other end carries the quadrant D E through a distance equal to the lap and lead of the valve; the supplementary port-opening is given by the oscillation of the quadrant D E which is worked by the levers and links F G H; the lever F is pinned to the connecting-rod at point K, which moves in an ellipse, the other end is attached to a sliding-block L; the link G is pinned to lever F at point M, the other end of G and one end of H are carried by a suspension-rod J, the link H is attached to an arm N, which forms part of the quadrant D E. The amount of port opening may be increased or diminished as the valve-rod O is moved from or to the centre of quadrant D E.

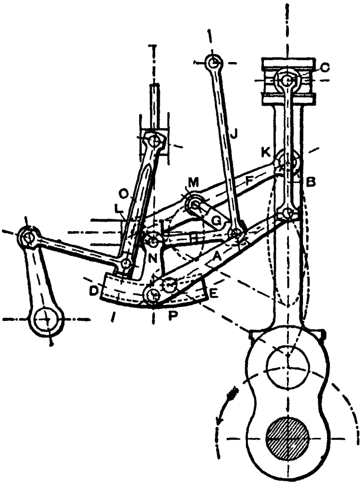


Fig. 77.—Radial Valve-Gear.

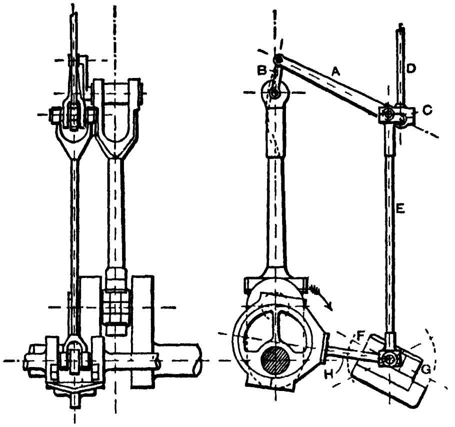


Fig. 78.—Single Eccentric Valve-Gear.

The Bryce-Douglas Single-Eccentric Valve-Gear, shown in Fig. 78, is exceedingly simple, and, as in the radial gear, the lead remains constant for any grade of expansion.

The lever A is attached by a link B to the cross-head, the end C is attached to the valve-spindle D; the lap and lead are given by the action of this lever, which has its fulcrum on the upper end of rod E.

The supplementary port-opening is given by the motion of a slide-block, which is attached to the end of the eccentric-rod H and the bottom of the connecting-rod E in the inclined plane F G. By varying the inclination of F G the engine can be reversed or the cut-off varied.

Morton's Valve-Gear is shown in Fig. 79. The chief feature of this gear is the means employed to correct the error in steam engines due to the angularity of the connecting rod. This correction is accomplished by means of the radiating crank A, centred in a projection P, on the connecting-rod, and actuated (in double-cranked engines, such as marine, and inside cylinder locomotives), by the piston.

The point A radiates equally across the centre-line of the connecting-rod, with sufficient relative travel to cause the point A to move in a regular elliptical path.

This corrected movement is conveyed to the valve through the valve-lever

F, and link C. The latter vibrates from a fixed centre in a constant path, in time with any increments of the piston's movements from either end of the stroke.

The overhung end G N of the lever F imparts the sum of the lap and lead travel of the valve. The centre of the valve-spindle being in line with the centre N when the engine is at either end of its stroke.

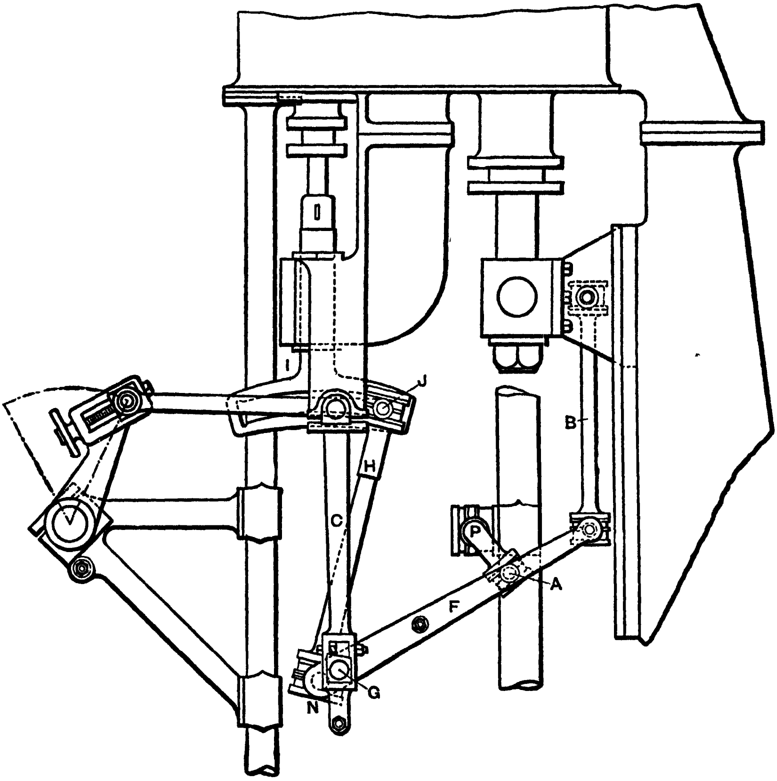


Fig. 79.—Morton's Valve-Gear.

The versed sine of the crank A and lever F must agree to give equality of vibration to the centre G.

The adjustable link H, with die-block J and quadrant I, is made to the radius of H, consequently the die-block J, in which there is little or no "slip," and link H may be put from go-a-head to go-a-stern position without moving the valve, lead being constant.

The whole motion is connected to the piston through the lever F and link B.

Joy's Valve-Gear, shown in Fig. 80, was designed to dispense with eccentrics. The main valve-lever E is pinned at D to a link B, one end of which is fastened to the connecting-rod at A and the other end maintained by the radius-rod C, which is fixed at the point C^1. The centre or fulcrum F of the lever E, partaking of the vibrating movement of the connecting-rod at the point A, is carried in a curved slide J, the radius of which is equal to the length of the link G, and the centre of which is fixed to be concentric with the fulcrum F of the lever when the piston is at either extreme end of its stroke. From the upper end of the lever E, the motion is carried direct to the valve by the rod G. By one revolution of the crank the lower end of the lever E will have imparted to it two different movements, one along the lower axis of the ellipse, travelled by the point A, and one through its minor axis up and down, these movements differing as to time and corresponding with the part of the movement of the valve required for lap and lead and that part constituting the port-opening for admission of steam. The former of these is constant and unalterable, the latter is controllable by the angle at which the curved slide J may be set with vertical. If the lever E were pinned direct to the connecting-rod at the point A, which passes through a practically true ellipse, it would vibrate its fulcrum F unequally on either side of the centre of the curved slide J, by the amount of the versed line of the arc of the lever E from F D: it is to correct this error that the lever E is pinned at the point D, to a parallel motion formed by the parts B and C, the point D performing a figure which is equal to an ellipse, with the error to be eliminated added, so neutralising its effect on the motion of the fulcrum F. The lap and lead are opened by the action of the valve-lever acting as a lever, and the port-opening is given by the incline of the curved slide in which the centre of that lever slides.

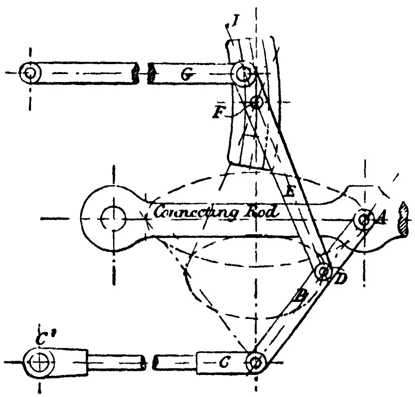


Fig. 80.—Joy's Valve-Gear.

Friction of Wood-Blocks used for Brakes on Railway Trucks.—The coefficients of friction of different kinds of dry wood when applied as brakes to railway wheels and the brake-pulleys of hoisting-engines are as follows: On smooth wheels and brake-pulleys of steel and wrought iron—Poplar ·63, Willow ·60, Elm ·55, Maple ·54, Beech ·52; Oak ·48.

On smooth wheels and brake-pulleys of cast-iron, the coefficients of friction are—Poplar ·40 Willow ·38, Elm ·37, Maple ·36, Beech ·35, Oak ·30.

Producer-Gas is generated in a plant consisting of the combination of a producer and a gas-engine ; and it is obtained by passing air and steam through incandescent fuel. In gas-producers on the suction principle, the air is drawn through the producer. The calorific power of producer-gas is from 140 to 150 thermal units per cubic foot, or about one-fourth of the value of town-gas, which is generally about 600 thermal units per cubic foot.

The power obtained from the coal used in a gas-producer, combined with a gas-engine, is very much greater than that obtained from it when used in a steam-boiler combined with a steam-engine. Producer-gas is automatically generated by the action of the engine at rates according to its varying consumption, and out of every 100 units of heat-energy contained in the coal 90 per cent. may be delivered to the engine. In steam-boilers the average heat-efficiency obtained is frequently only 65 per cent. The gas-making process in the producer only goes on while the engine is working, therefore no surplus gas is ever made.

Cost of Working Suction Gas Plants.—Engines worked by suction gas develop power very economically. The cost of the production of power by different kinds of engines varies so considerably that it cannot be averaged, but the results of numerous careful tests, under ordinary working conditions, show that it is frequently as given in the following table, which includes the cost of fuel, attendance, depreciation, interest on capital, insurance, and all the usual expenses of working the engines.

TOTAL COST OF WORKING DIFFERENT KINDS OF ENGINES PER BRAKE-HORSE-POWER PER HOUR.

Description.	Brake-Horse-Power 30 to 50.	Brake-Horse-Power 70 to 170.	Brake-Horse-Power 200 to 500.
	Penny.	Penny.	Penny.
Electric motors . . From *2d.* down to	1·50	1·25	1·00
Steam-engines using saturated steam . . .	1·25	·75	·60
Gas-engines using very low-priced town-gas .	1·00	·70	·50
Oil-engines . . . From 1½*d.* down to	·90	·55	·45
Gas-engines using producer-gas from anthracite coal	·80	·50	·40
Highly economical steam-engines using superheated steam	·70	·45	·35
Gas-engines using producer-gas from gas coke	·60	·40	·30
Gas-engines using Mond-gas	·60	·40	·30

The cost of working small engines of from 7 to 20 brake-horse-power is frequently from 50 to 100 per cent. more than that given in the first column of this table.

A brake-horse-power costing ·45 penny per hour is = ·45 × 1·333 = ·6*d.* per kilowatt-hour.

Suction Gas-Producers.—The suction gas-producer shown in Fig. 80A consists of a cylindrical fire-brick-lined chamber, separated from the outside metal skin by a coating of sand. The fire-brick lining rests on a metal ring supported on two cast-iron segmental shaped boxes, termed superheaters, placed at the hottest part of the fire, and mounted on a flat plate carried across the producer. This plate has a hole in the centre, in which rests the bars of the fire-grate.

In this way a pit is formed immediately below the fire-grate, and in this pit the steam and air used in the gas-making process mix before passing through the fire.

The arrangement of the fire-grate permits the removal through the fire-doors of any clinker that forms into cakes over the grate. In addition to this, means are provided by which the clinker can be removed from the bottom of the fire-brick lining, should it form there, and the clinker immediately above the grate can be broken up while the plant is at work.

On the top of the producer there is a feeding-hopper, through which the fuel is introduced. Around the cylindrical bell, defining the depth of fuel in the producer, is formed the well of the saturator or boiler. Cold water is introduced into the bottom of this well and fills the rest of the saturator to a level defined by an overflow pipe.

The saturator is shaped like a flat dish, extending to the outside shell of the producer. This dish has a series of baffle-plates on its under surface, which form passages through which the hot gas has to pass, giving up its heat to the water before going to the coke-scrubbers to be cleaned. Two vertical steam-pipes form the connection between the saturator and superheaters.

The requisite steam is raised in the saturator by extracting the heat of the gas as it passes from the fire. This is termed the regenerative principle. The forward motion of the piston of the engine draws the air and steam through the producer.

The water consumed does not exceed one gallon per brake-horse-power per hour for all purposes. With anthracite at 40*s*., the cost of the fuel per brake-horse-power is one-fifth of a penny per hour.

The suction gas-producer shown in Fig. 80B is on the regenerative principle, and is similar in appearance to the above-described producer, but it varies in details of construction.

It has an annular vaporiser surrounding the coal-hopper, and heated by the gas from the fire. The air enters a helical passage which winds round the pipe carrying the hot gas from the producer to the scrubber, and thence flows into the vaporiser. The water is introduced into a tube in the centre of the gas-pipe, where it is heated before entering the vaporiser.

The consumption of small anthracite by this suction gas-producer is only about 1 lb., and of suitable coke about 1¼ lbs., per brake horse-power of the gas engine per hour.

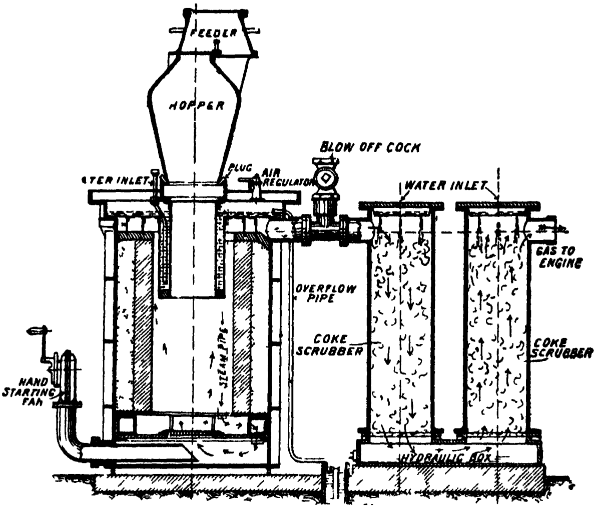


Fig. 80A.—Suction Gas Producer by Crossley Bros., Limited, Openshaw, Manchester.

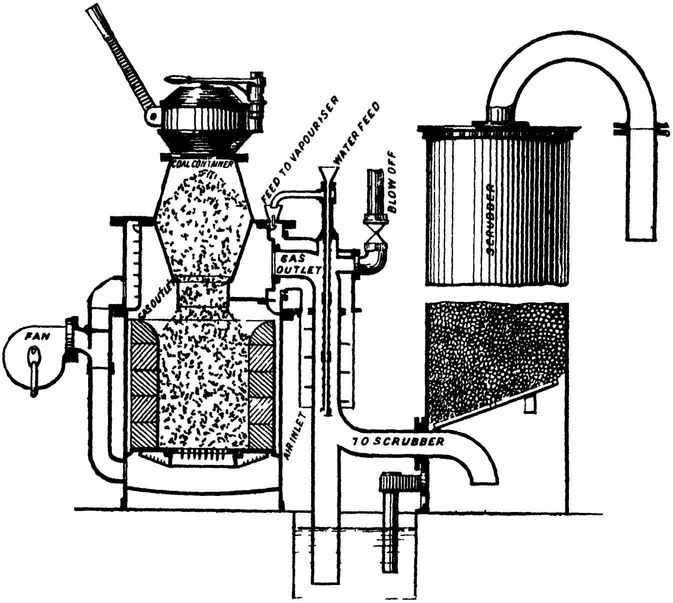


Fig. 80B.—Suction Gas-Producer by the National Gas Engine Co., Limited, Ashton-under-Lyne.

Tests of Suction Gas-Producer Plants.—Several tests of suction gas-producers were made by the Highland and Agricultural Society the principal results of which are given in the following Table:—

Trials of Suction Gas-Producer Plants of about 20 Brake-Horse-Power Capacity.

Full Load Trial.

Exhibitor.	The Campbell Gas Engine Co., Halifax.	Crossley Bros., Ltd., Manchester.	The National Gas Engine Co., Ashton-under-Lyne.	Tangyes Ltd., Birmingham.
Declared brake h.-p. at full wkg. load	18	16	20	19
Effective load on brake, lbs. . .	201	184·8	190·5	195·15
Revolutions per minute, mean . .	192·4	189·2	193	197·9
Brake h.-p.	20·44	15·35	20·57	19·98
Diameter of cylinder, inches . .	9·5	8·5	10	10
Stroke, inches	18	20	18	19
Mean effective prssre., lbs. per sq. in.	82	73·6	83·7	72
Explosions per minute, mean . .	76·8	86·5	85·4	86·4
Indicated h.-p.	23·73	18·25	25·54	23·45
Mechanical efficiency . per cent.	86·1	84·1	80·6	85·3
Coal per brake h.-p. per hour, lbs. .	·93	·77	·80	·83

Half Load Trial.

Effective load on brake, lbs. . .	103·15	104·25	98·5	104·2
Revolutions per minute, mean . .	196·1	198	190·3	198·7
Brake h.-p.	10·69	9·06	10·48	10·72
Mean effective prsr., lbs. per sq. in. .	75·6	77·8	80·6	77·9
Explosions per minute, mean . .	53·1	58·3	51·3	49 7
Indicated h.-p.	15·12	13·0	14·76	14·59
Mechanical efficiency . per cent.	70·7	69·7	71 0	73·5
Coal per brake h.-p. per hour, lbs. .	·92	·96	·95	1·08
Average coal consumption per brake h.-p. per hour on full and half load trials combined, lbs. . .	·93	·86	·86	·92
Capacity of producer per declared brake h.-p. . . cubic foot	·232	·270	·295	·124

Full Load Trial of Suction Gas-Producer Plants of about 8 Brake-Horse-Power Capacity.

Effective load on brake, lbs. . .	87·85	...	102·6	80·75
Revolutions per minute, mean . .	232·5	...	219·8	224·4
Brake h.-p.	8·25	...	9·74	8·34
Diameter of cylinder, inches . .	7	...	7	7
Stroke, inches	12	...	15	16
Mean effective prse., lbs. per sq. in. .	77·8	...	83·8	75·8
Explosions per minute, mean . .	106·4	...	97·2	92·1
Indicated h.-p.	9·66	...	11·88	10·86
Mechanical efficiency . per cent.	85·4	...	82	76·8
Coal per brake h.-p. per hour lbs.	1·22	...	·84	1·25

Gas-Engines.—A gas-engine is superior to a steam-engine as a heat-engine, or machine for converting heat into work. The absolute temperature in the cylinder of a gas-engine is from 3000° to 3500° Fahr. Taking the higher temperature, and assuming that of the exhaust gases to be 1230° Fahr., the theoretical highest efficiency of a gas engine is = (3500—1230) ÷ 3500 = 65 per cent.

In the case of a condensing steam-engine using steam of 250 lbs. per square inch absolute pressure, the absolute temperature of which is 860·9° Fahr., and exhausting it at an absolute temperature of 622·3° Fahr., its theoretical efficiency is only = (860·9—622·3) ÷ 860·9 = 28 per cent.

The "Otto" may be regarded as the parent or prototype of gas-engines over 2 horse-power. It is a compression-engine, of simple design and strong construction, and requires little attention in working. In general appearance it resembles a horizontal steam-engine, but here the resemblance ceases. It is single-acting, the cylinder being open at the front end. The engine acts alternately as a pump for drawing in and compressing its charge, and as a motor for utilising this charge when fired. The fly-wheel makes two complete revolutions for every charge of gas admitted. The first outstroke draws in the compound charge; by the first instroke the charge drawn in by the previous outstroke is compressed to about one-third its volume; at the end of this first instroke or the beginning of the second outstroke, the compressed charge is ignited, when the expanding gases propel the piston to the end of the stroke; and the second instroke expels the products of combustion and completes the cycle of operations which are continually repeated when the engine is working up to its full power. When the engine is working within its power, the gas is temporarily cut off by the governor, and the engine simply works as a pump for drawing in, compressing and expelling the air.

The charge to be ignited is not a uniform mixture of gas and air, but consists of a compound charge of incombustible gas, *i.e.* combustion products or air next the piston combining gradually with a mixture of gas and air that becomes stronger and more readily ignitible as it reaches the point where it is fired. The effect of this so-called stratification is that whilst the charge is as easily ignited as a uniform charge of highly explosive mixture, the presence of a large quantity of diluent, causes the combustion of the complete charge to be effected gradually. The result of this is most important. In the first place it prevents the sudden shock that occurs when a uniform mixture is ignited, and which is a sure indication of waste. In the second place, it ensures the pressure being sustained to the end of the stroke.

The initial pressure of the gas in the cylinder when ignited at the beginning of the stroke is about 170lbs. per square inch. The gases expand to a pressure of about 35lbs. at the end of the stroke. The average pressure is about 70 lbs. per square inch on the piston.

The consumption of gas varies from 14 cubic feet per indicated horse-power in the largest sizes of engines to 25 cubic feet in the smallest.

Small non-condensing steam-engines are generally very extravagant in the consumption of fuel. Their coal consumption, under ordinary working conditions, is frequently as great as 10 lbs. per indicated horse-power per hour. They cannot, therefore, compete favourably with small gas-engines. Gas-engines, even when using moderately high-priced town-gas frequently only cost about one penny per indicated horse-power per hour. Small steam-engines frequently cost nearly twice as much as this.

Tests of Gas-Engines.—Several careful tests were made of three gas-engines, "The Otto," "The Cycle," and "The National," the principal results of which are given in the following pages.

Test of "The Otto Gas-Engine."—The diameter of the cylinder of this engine was 9½ inches, and the length of stroke 18 inches. The results of the test were as follows:—

Revolutions per minute	160·10
Explosions per minute	78·40
Mean initial-pressure	196·90
Mean effective-pressure	67·90
Indicated horse-power	17·12
Brake load, net	177·40
Brake horse-power	14·74
Mechanical efficiency	·861
Gas per hour, main	351·80
Gas per hour, ignition	3·50
Total	355·30
	cubic ft.
Gas per indicated horse-power per hour, main	20·55
Gas per indicated horse-power per hour, total	20·76
Gas per brake horse-power per hour, main	23·87
	cubic ft.
Gas per brake horse-power per hour, total	24·10
Gas per net horse-power, available after allowing for counter-shaft	27·4
Water per hour, in lbs.	713
Rise of temperature	128°
Horse-power absorbed in driving the engine	2·38
Mean-pressure during working-stroke equivalent to work done in pumping-strokes	2·19
Corresponding indicated horse-power	·55

This experiment lasted six hours continuously, with the engine working at full power.

Test of "The Cycle Gas-Engine" (Atkinson's).—The diameter of the cylinder of this engine was 9½ inches, the suction-stroke 6·33 inches, the compression-stroke 5·03 inches, the working-stroke 11·13 inches, and the exhaust-stroke 12·43 inches. The radius of the crank of the engine was 12⅞ inches. During one revolution of the crank-shaft the piston performs the following evolutions:—Starting from the extreme back-end of cylinder, it advances, drawing in gas and air; it then retires, compressing the mixture, but only to a point at some distance from the end of the cylinder; the charge is then ignited, and the working-stroke performed; and lastly, the piston retires to the end of the cylinder, ejecting the whole of the products of combustion. The results of the test were as follows:—

Revolutions per minute	131·10
Explosions	121·60
Mean initial-pressure	166·00
Mean effective-pressure	46·07
Indicated horse-power	11·15
Brake-load net	130·50
Brake horse-power	9·48
Mechanical efficiency	·85
Gas per hour, main	209·80
Gas per hour, ignition	4·50
Gas per hour, total	214·30
	cubic ft.
Gas per indicated horse-power per hour, main	18·82
Gas per indicated horse-power per hour, total	19·22

	cubic ft.
Gas per brake horse-power per hour, main	22·14
Gas per brake horse-power per hour, total	22·61
Water per hour, in lbs.	680
Rise of temperature	52·2°
Horse-power absorbed in driving the engine	1·67
Mean-pressure during working-stroke equivalent to work done in pumping-stroke	1·00
Corresponding indicated horse-power	·26

This experiment lasted six hours continuously, with the engine working at full power.

The "National" Gas Engine:

FUEL CONSUMPTION.—The gas consumptions are as follows:—

	"Fag" series engines		"Barg" series engines	
	B.Th.U. nett per b.h.p. hour	Calories nett per metric b.h.p. hour	B.Th.U. nett per b.h.p. hour	Calories nett per metric b.h.p. hour
Full load	9,500	2,360	9,000	2,240
Three-quarter load	10,500	2,610	10,000	2,480
Half load	12,000	2,980	11,500	2,860

These consumptions are subject to a tolerance of 2½ per cent.

	"Fax" series engines		"Barx" series engines	
OIL	lb. per b.h.p hour	grammes per metric b.h.p. hour	lb. per b.h.p. hour	grammes per metric b.h.p. hour
Full load	0.39	174	0.38	170
Three-quarter load	0.39	174	0.38	170
Half load ...	0.44	107	0.42	188
GAS	B.Th.U. nett per b.h.p. hour	Calories nett per metric b.h.p. hour	B.Th.U. nett per b.h.p hour	Calories nett per metric b.h.p. hour
Full load	9,500	2,360	9,000	2,240
Three-quarter load	10,500	2,610	10,000	2,480
Half load	12,000	2,980	11,500	2,860

LUBRICATING OIL CONSUMPTION.—On engines of both "Fag" and "Barg" series, and calculated on the rated output, 2,500 b.h.p. hours are obtainable from one gallon of lubricating oil (560 metric b.h.p. hours per litre).

Oil-Engines.—There are several forms of Oil-Engines which work economically with ordinary mineral oil. In these engines the oil is delivered in a fine spray to a vaporising chamber, where it is converted into vapour by heat supplied by a lamp on starting the engine, and afterwards by exhaust vapour which envelops the chamber. The engine has a four-cycle movement, that is, the piston on its first or forward stroke draws in a charge of vapour through an inlet valve. This charge is compressed on the second stroke, and at the moment of compression an electric spark from a small battery explodes the charge and drives the piston out, thus making the third stroke. The fourth stroke drives the spent vapour out of the cylinder through an exhaust valve.

The consumption of fuel-oil by these engines is from ½ lb. to 1 lb. per indicated horse-power per hour; the larger the engine the less is generally the consumption of fuel-oil.

The Diesel Oil-Engine.—This engine differs from some types of oil-engines in that the mixture of sprayed oil-fuel and air does not explode, but is burnt, in the cylinder.

The engine works on the four-stroke cycle. On the first descent or out-stroke of the piston, air only, and not an explosive mixture, is drawn into the cylinder through a tube, closed at the end and provided with a series of narrow slits to serve as a rough filter and silencer. On the return or upward stroke of the piston this air is compressed to about 500 lbs. pressure per square inch into a small clearance space at the top of the cylinder. This compression raises the temperature of the air to about 1,000° Fahr.—a heat sufficient to ignite the finely-divided spray of fuel which is injected into it by a jet of air stored in a steel reservoir at a pressure of from 750 to 800 lbs. per square inch.

On entering the hot-air in the cylinder, this spray of fuel-oil, every globule surrounded by the air which atomises it, burns steadily as long as it is injected into the cylinder. At every working stroke, some oil is thus burned, the quantity being regulated by a pump controlled by a governor. At the end of the working stroke the exhaust valve opens, and the products of combustion are expelled during the next in-stroke, completing the cycle.

The following particulars are extracted from the report, by Mr. Michael Longridge, of the test of a three-cylinder Diesel oil-engine of 500 brake-horse-power, at a speed of 150 revolutions per minute:—

	Full Load.	Half Load.
Oil consumed per indicated horse-power . .	·3202 lb.	·2828 lb.
Oil consumed per brake-horse-power . . .	·4103 lb.	·4196 lb.
Mechanical efficiency, per cent.	72·3	—
Thermal efficiency, per cent.	39·6	44·9

With this rate of consumption, the cost of fuel-oil per brake-horse-power per hour is only ·088*d.*, and 11 brake-horse-power were developed for one penny per hour.

"Ford"

INDUSTRIAL ENGINE UNITS. MODEL "51" (30 H.P.)

ENGINE.—Type, V-8-90 degrees "L" Head. Bore, $3\frac{1}{16}$ inches. Stroke, $3\frac{3}{4}$ inches. Piston displacement, 221 cubic inches. Brake h.p., 81·5 at 3,700 R.P.M. Torque, 138 lbs./ft. at 1,700 to 2,200 R.P.M. Compression ratio, 5·32 to 1. Compression pressure, 110 lbs, at 2,500 r.p.m. Firing order, 1-5-4-8-6-3-7-2. Sump oil capacity, 4 quarts. Sump ventilation, directed flow. Engine mounting, 3 point suspension with rubber mountings. Weight with clutch and 4 speed transmission, 614 lbs.

CYLINDER BLOCKS.—Type, Single unit casting integral with sump upper-half. Offset of cylinders, $\frac{3}{16}$ inch. Material, Ford cast alloy iron.

CYLINDER HEADS.—Type, heavy duty. Material, cast iron.

CRANKSHAFT.—Type, Counterbalanced 90 degrees throw. Weight, 65 lbs. Length, $24\frac{15}{32}$ inches. No. of main bearings, 3. Total main bearing surface area, $35\frac{11}{32}$ square inches. Length of main bearings: front, $1\frac{11}{16}$ inches; centre, $1\frac{11}{16}$ inches; rear, $2\frac{1}{4}$ inches. Diameter, 2 inch main bearings and pins. Length of crank pin bearings, $1\frac{15}{16}$ inches. No. of counterweights, 6-cast integral. Material, special cast alloy steel. Main bearing material, Babbitt. Pin bearing material, copper lead.

FLYWHEEL.—Material, cast iron. Flywheel ring gear, pressed steel. Weight of flywheel, 32 pounds. Flywheel gear ratio to starter drive, 11·2 to 1.

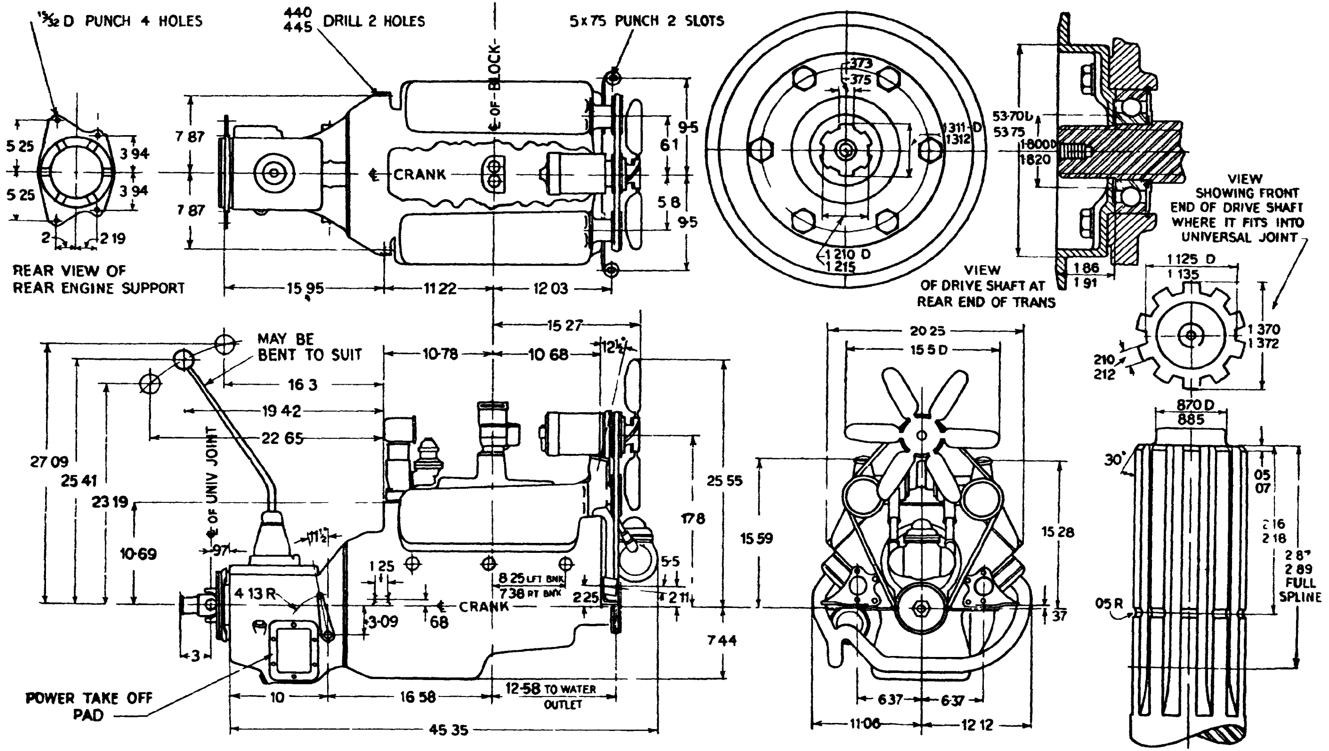
CONNECTING RODS.—Length, 7 inches centre to centre. Weight, 469-473 grams. Big end bearing, $2\frac{7}{32}$ inches diameter, $\frac{7}{8}$ inch long. Piston pin bearing, $\frac{3}{4}$ inch diameter, $1\frac{5}{16}$ inches long. Material, special bronze.

PISTONS.—Material, lightweight cast alloy, open split skirt. Length, 2·97 inches. Weight, 287-291 grams. No. of piston rings, 2 compression, 1 oil control. Width of compression rings, $\frac{3}{32}$ (·0915 to ·092) inch. Width of oil control ring, $\frac{5}{32}$ (·1545 to ·155) inch. Piston pin, full floating, positioned in rod. Piston pin material, machined seamless steel tubing. Piston pin diameter, $\frac{3}{4}$ inch.

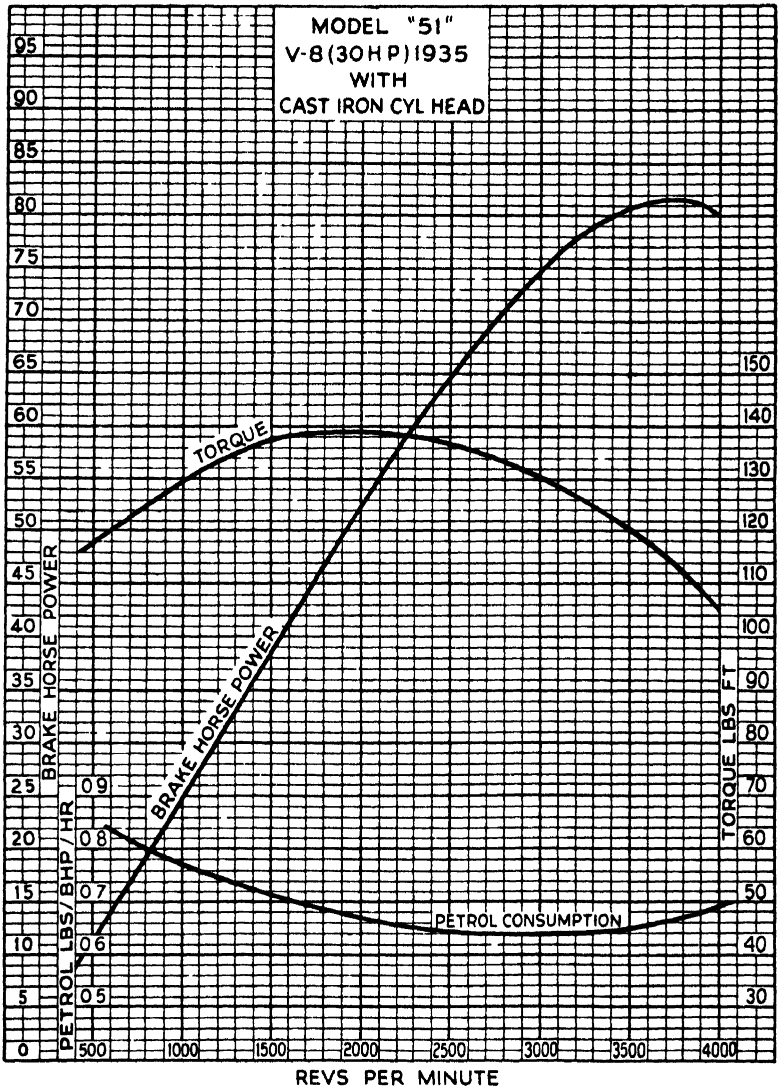
CAMSHAFT.—Diameter, 1 inch between cams. Bearings, 3 Babbitt lined, steel backed. Bearing diameter, $1\frac{51}{64}$ inches. Bearings length: front, $1\frac{19}{32}$ inches; centre, $1\frac{5}{16}$ inches; rear, $1\frac{19}{32}$ inches. Cam lift, 0·294 inch. Camshaft gear, bakelized material. Camshaft material, cast alloy.

PUSH RODS.—Type, lightweight, hollow cast. Material, special ford cast alloy steel. Diameter, ·999 to ·9995 inch.

VALVES.—Arrangement, L. Material, Chrome-nickel alloy steel. Diameter of valve head at seat, $1\frac{31}{32}$ inches. Angle of seat, 45 degrees. Stem diameter, $\frac{5}{16}$ inch. Diameter of stem end, ·550 inch. Tappet clearance, ·0125 to ·0135 inch. Exhaust valve seats, high tungsten chrome alloy (cast high speed steel at Dagenham). Valve timing: intake opens, $9\frac{1}{2}$° before top centre; intake closes, $54\frac{1}{2}$° after bottom centre; exhaust opens, $57\frac{1}{2}$° before bottom centre; exhaust closes, $6\frac{1}{2}$° after top centre. Valve spring length (in position), $2\frac{1}{8}$ inches. Valve spring pressure (valve closed), 32 to 36 pound (valve open), 62 to 66 pounds.



General Dimensions of a "Ford" 8-Cylinder Engine and 4 Speed Transmission Assembly. (Messrs. Ford, Dagenham)



Torque, Brake Horse Power and Fuel Consumption of a 30 H P. "Ford" Engine.

LUBRICATION (ENGINE).—Type, full pressure feed to all main, connecting rod and camshaft bearings and timing gears. Oil pump, gear type. Capacity, 1·567 gallons per minute at engine speed of 1000 r.p.m. of camshaft. Oil pump drive, gear at rear of camshaft. Normal oil pressure, 30 lbs. Sump oil capacity, 4 quarts. Oil level gauge, bayonet dip rod.

COOLING.—No. of water pumps, one in each cylinder head. Type of pumps, centrifugal. Shaft material, stainless steel. Pump drive, V-belt. Radiator type, tube and fin. Cooling surface, 443 square inches. Core thickness 3 inches. No. of fins, 237 spaces 9½ per inch. No. of tubes, 154 flat tubes arranged in four staggered rows. Capacity of cooling system, 5·2 gallons. Radiator hose diameter, top and bottom, 1¾ inches. Hose length: top, 12 inches; bottom, 5½ inches. Thermostatic control, 2 water line thermostats. Fan type, 6 blade. Fan diameter, 15½ inches. Fan belt, V-type angle of V 28°. Fan belt width (max.), ⅝ inch. Fan speed, 1·43.

MANIFOLDS.—Intake, dual type in single casting with hot spot. Material, cast iron. Exhaust, separate manifold for each cylinder block. Material, cast iron.

CARBURETTOR.—Type, Stromberg dual down-draught. Air cleaner and silencer, standard equipment.

PETROL SYSTEM.—Petrol feed, mechanical diaphragm pump, cam operated through push rod.

ELECTRICAL UNITS.—Distributor, single unit with ignition coil and condenser. Waterproof housing. Distributor drive, direct from front end of camshaft. Spark advance, full automatic vacuum control. No. of breaker arms, two. Breaker gap setting, ·012 to ·014 inch. Spark plug size, 18 mm. Spark plug gap setting, ·025 inch. Generator, 6 volt air cooled third brush regulation. Front bearing, two opposed tapered roller. Normal charging rate, 12 amperes. Armature speed, 1·43 times engine speed. Starter motor, 6 volt. Starter drive, Bendix type. Normal engine cranking speed, 100 r p.m. Starter pinion to flywheel, gear ratio, 11·2 to 1. Battery, 6 volt. Capacity, 90 ampere hours. No. of cells, 3. No. of plates, 17 per cell. Grounded terminal, positive.

CLUTCH.—Type, dry single plate with plate pressure increased by centrifugal force. No. of driven plates, 1—ventilated type with damper springs Diameter (outside), 11 inches. Thickness of facing, $\frac{9}{64}$ inch. Material clutch facing, moulded asbestos composition. Total friction area, 123·7 square inches. Weight of driven disc assembly, 4·643 lbs. (40 lbs. 10 oz). Weight of pressure plate assembly, 18·187 lbs. (18 lbs. 3 oz.). Clutch plate pressure, 1·215 lbs. at zero speed.

TRANSMISSION (FROM SPEED).—Type, selective sliding gear. No. of speeds, four forward, one reverse. Gear ratios: top, 1 to 1; 3rd, 1·69 to 1; 2nd, 3·09 to 1; 1st, 6·4 to 1; Reverse, 7·82 to 1. Trans. oil capacity, 4·17 pints. Power take-off opening, 6 bolt.

ACCESSORIES AND SPECIAL EQUIPMENT EXTRA TO STANDARD.

Oil-bath Type Air Cleaner.—This is recommended where engines are required to operate under extremely dusty conditions.

Governor.—Prevents racing engine.

Power Take-off.—Easily attached to right side of gear box.

Extra Cooling Capacity.—Obtainable by use of special 17 inch fan, radiator core, double sheave pulley, water pump shaft assemblies, cylinder heads and gaskets, crank pulley, and double sheave generator pulley.

SECTION II.

HYDRAULIC MEMORANDA: WATER-SUPPLY: PUMPS, PIPES, WATER-POWER, &c.

SECTION II.

HYDRAULIC MEMORANDA: WATER-SUPPLY: PUMPS, PIPES, WATER-POWER, &c.

Water is composed of oxygen and hydrogen, in the proportion of one part of hydrogen and eight parts of oxygen by weight.

WEIGHT AND CAPACITY OF WATER.

A cubic inch of water = ·0361 lb.
A cubic foot of water = 62·42 lbs.
A cubic foot of water = ·557 cwt.
A cubic foot of water = ·028 ton.
A cubic foot of water = 6·24 gallons.
1 cwt. of water = 1·8 cubic feet.
1 cwt. of water = 11·2 gallons.
1 ton of water = 35·9 cubic feet.
1 ton of water = 224 gallons.
1 lb. of water = 27·7 cubic inches.
1 lb. of water = 0·16 cubic ft.
1 cylindrical inch of water = ·0284 lb.
1 cylindrical foot of water = 49·10 lbs.
1 gallon of water = 10 lbs.
11·2 gallons of water = 112 lbs.
224 gallons of water = 2240 lbs.
1·8 cubic feet of water = 112 lbs.
35·84 cubic feet of water = 2240 lbs.
277·274 cubic inches = 1 gallon.
353 cylindrical inches = 1 gallon.
Cubic inches multiplied by ·0036 = gallons.
Cubic feet multiplied by 6·24 = gallons.
Cubic inches divided by 277·274 = gallons.
Gallons multiplied by ·16045 = cubic feet.
Cylindrical feet multiplied by 4·895 = gallons.
1 cubic foot of town's sewage = 62·42 lbs
1 cubic foot of ice at 32° = 58 lbs.
1 lb. of ice at 32° = 30·06 cubic inches.

1 lb. of ice at 32° = ·017 cubic ft.

Water in freezing expands to the extent of $8\frac{1}{2}$ per cent.

The specific heat of ice is one-half the specific heat of water.

Ice 3 inches thick, will bear the passage of infantry; 5 inches thick of cavalry and light guns.

A cubic foot of fresh snow = 6 lbs.

Snow has twelve times the bulk of water.

A cubic foot of sea water = 64·10 lbs.

Weight of sea water = 1·027 the weight of fresh water.

35 cubic feet of sea water = 1 ton.

1 cubic yard of sea water weighs 15 cwt. 1 qr. 20 lbs.

A column of water 1 inch diameter and 12 inches high = ·341 lb.

A column of water 1 inch square and 12 inches high = ·434 lb.

The capacity of a cylinder 1 inch diameter and 12 inches long = ·034 gallon.

The capacity of a cylinder 12 inches diameter and 12 inches long = 4·895 gallons.

The capacity of a cylinder 1 inch diameter and 1 inch long = ·00283 gallon.

The capacity of a 1-inch cube = ·0036 gallon.

The capacity of a 12-inch cube = 6·24 gallons.

The capacity of a sphere 1 inch diameter = ·00188 gallon.

The capacity of a sphere 12 inches diameter = 3·26 gallons.

The cube of the diameter of a sphere in feet multiplied by 3·26 = gallons.

Or the cube of the diameter of a sphere in inches multiplied by ·00188 = gallons.

A column of water produces approximately a pressure of half a lb. per square inch, for every foot in height.

Pressure of Water.—The side of any vessel containing water sustains a pressure = to the area of the side in feet multiplied by half the depth in feet, that product multiplied by 62·5 will give the pressure in lbs. on each side of the vessel.

The pressure in lbs. on the bottom of a vessel is = to the area of the bottom in feet multiplied by the depth of water in feet, that product multiplied by 62·5 will give the pressure in lbs.

Contents of Cisterns.—*To find the number of gallons* contained in a cistern. Multiply the length, width, and depth together, all in feet. This will give the contents in cubic feet, which multiply by 6·24, and the product will be the number of gallons. If the dimensions are in inches use ·003607 in place of 6·24.

Two dimensions of a cistern being given to find the third, to contain a given number of gallons, multiply the required number of gallons by ·16046 if the dimensions are in feet, or by 277·274 if the dimensions are in inches, and divide the result by the product of the two given dimensions. The quotient will be the third dimension required.

To find the number of gallons contained in a cylinder, multiply the square of the diameter in feet by the length in feet of the cylinder, and multiply the product by 4·895; or multiply the square of the diameter in inches by the length in feet, and multiply the product by ·034; or multiply the square of the diameter in inches by the length in inches, and multiply the product by ·00283.

The diameter of a cylinder being given, to find the length, multiply the number of gallons by ·2043, and divide the product by the square of the diameter in feet, and the quotient is the length in feet.

The length of a cylinder being given, to find the diameter, multiply the number of gallons by ·2043, and divide the product by length in feet, and the square root of the quotient is the diameter in feet. If the dimensions are in inches, use 353 in place of ·2043.

WATER AND WATER-SUPPLY.

Water is very variable in composition, because it is influenced by the geological formation of the district through which it flows. Water from chalk-springs is generally pure and wholesome, clear and sparkling, of a slight bluish tint, and contains from 6 to 20 grains of mineral matters per gallon. Its temperature is generally about 52° Fahr. It is hard, but softens considerably by boiling. Water from limestone and gypsum strata is hard, softens less by boiling, and is not so wholesome as chalk-water, but it is generally clear and sparkling and of agreeable taste.

Water from millstone-grit is pure, and contains from 4 to 9 grains per gallon of mineral matters. Water from granite is pure, and contains from 2 to 6 grains of mineral matters per gallon. Water from clay-slate is generally pure, and contains from 3 to 5 grains of mineral matters per gallon.

Water from gravel and loose sand is generally pure when the gravel and sand are free from impurities, but water from sand rich in salts is impure and unwholesome. Water from impure sand generally contains from 50 to 100 grains of mineral matters per gallon.

Water from clay, or from a mixture of clay and sand, is generally impure, and contains from 30 to 130 grains of mineral matters per gallon. Surface-water from cultivated land, subsoil-water, marsh-water, ditch-water, and water from shallow wells and ponds, are all more or less impure, and dangerous to health.

Drinking-water.—An abundant supply of pure water, perfectly protected from impurity in storage, and free from contamination in distribution, is a sanitary necessity in every community.

Pure and wholesome water is soft, clear, transparent, slightly sparkling, well aërated, without taste, contains no visible suspended matter, and is either colourless or of a bluish-tint.

Unwholesome water has generally considerable permanent hardness and suspended matter, with turbidity; and either a moderately palatable flat taste, or a marked taste, with or without smell, and a yellow or brown colour. A yellow or yellowish-white tint may be due to clay or sand; a light-brown tint to animal organic matter, or sewage; a darkish-brown tint to vegetable-humus, or to peat; and a green tint to vegetable matter.

Water may be Purified by filtration through porous substances, such as coral-limestone, spongy-iron, compressed-sponge, coke and charcoal, and through beds of small pieces of broken stock-bricks and sand. But the best method of purification is by the agitation of the water with solid particles of granulated iron, such as cast-iron-borings or turnings, and subsequent filtration through a layer of sand. Iron is inimical to animal and vegetable life, and the treatment of water with iron prevents the development of those microbes which cause fermentation and putrefaction of animal matter.

Rain Water should be collected and stored in districts where there is a scarcity of water. If not badly contaminated it may be purified by the addition of 10 to 12 grains of alumino-ferric cake, and 3 to 4 grains of ordinary slacked-lime per gallon of water, the ingredients being added separately. After agitation and settlement the precipitate falls to the bottom, carrying the impurities with it, and leaving about 95 per cent. of the depth clear and colourless. The purified water may be drawn off, or the precipitate removed by filtration through sand. This process may be used for the purification of many other impure waters.

Domestic Water-supply.—As cleanliness cannot be defined, it is difficult to state the minimum quantity of water absolutely necessary to maintain the healthy existence of each person of a household, but it may be estimated approximately from the following data, which includes the water used for washing purposes.—

In some cottages, without water-closets or baths, for which the water was carried from a well at a distance, 4½ gallons of water were used per head per day, with very imperfect cleanliness.

In a row of cottages, without water-closets or baths, the smallest quantity of water found to be requisite for even moderate cleanliness, was 7 gallons per head per day.

In a row of small villas, without baths, but with water-closets, 12 gallons of water were used per head per day in winter, and 13½ gallons per head per day in summer, with perfect cleanliness.

The minimum quantity of water in gallons per head per day, sufficient for all the requirements of a clean household, without allowance for waste, may be averaged as follows:—

Water for drinking and making tea and coffee . .	½	gallon.
Water for cooking purposes	1	,,
Water for washing the house and utensils . . .	2	,,
Water for laundry purposes	2½	,,
Water for water-closet	4	,,
Water for bath	5	,,

Equal a total quantity of water per head per day of 15 gallons.

Hospital Water-supply.—The quantity of water per head per day necessary for hospitals is at least double that requisite for domestic use, in consequence of the larger quantity required for bathing, washing, and cleaning purposes. A supply of 30 gallons per head per day is necessary.

Water-supply for Stables.—A horse, on an average, drinks 8 gallons of water per day doing light work, and 10 gallons per day doing heavy work. For washing horses, 3 gallons of water are necessary for each horse per day, and for washing and cleaning stables and carriages 4 gallons are required for each horse per day. Altogether, 17 gallons of water are required per horse per day for stable use.

Drinking-water for Animals. — The quantity of drinking-water required by various animals in gallons per head per day is as follows:—

Pigs	¾	gallon.
Sheep	1	"
Donkeys	5	gallons.
Ponies	6	"
Mules	7	"
Oxen	8	"
Cows	9	"
Horses	10	"
Camels	12	"
Elephants	28	"

Towns' Water-supply.—A liberal supply of water is necessary in towns for efficient flushing of the sewers. The quantity of water-supply for the general purposes of domestic supply, cleaning streets, flushing sewers, extinguishing fires, and for use in manufactories, should not be less than 30 gallons per head per day.

Discharge of Pipes for Water-supply.—The quantity of water discharged by ordinary cast-iron pipes, when full of water running under pressure, may be found by the following rule, deduced from careful experiments.

Rule: Multiply the fifth power of the internal diameter of the pipe in inches by the head of water in feet, divide the product by the length of the pipe in feet, and the square root of the quotient multiplied by 4.5, will give the quantity of water discharged per minute in cubic feet, which multiplied by 6·24 will give the quantity of water in gallons discharged per minute.

Example: Required the discharge of a line of pipes 6 inches diameter 2600 feet long, when full of water running under a head of 40 feet.

Then $\frac{6 \times 6 \times 6 \times 6 \times 6 \text{ inches} \times 40 \text{ feet}}{2600 \text{ feet length of pipe}} = 120$, and $\sqrt[2]{120} = 10{\cdot}95$ $\times\ 4{\cdot}5 = 49{\cdot}275$ cubic feet of water flowing per minute, and $49{\cdot}275 \times 6{\cdot}24 = 308$ gallons, the quantity of water discharged by the line of cast-iron pipes per minute.

The discharge of pipes is considerably diminished by rough surfaces and incrustation.

PUMPS FOR WATER-SUPPLY.

Load on the Bucket of a Pump.—At whatever height a pump delivers water, whatever may be the inclination and size of the suction and delivery-pipes, the bucket of the pump supports a weight, independent of frictional resistances, equal to that of a column of water having a base equal in area to that of the bucket, of a height equal to the difference of level of the water, from which the pump draws its supply, and the point of delivery of the water. If the difference in level, or the height in feet the water is lifted, be represented by H, the diameter of the bucket in feet by D, and the weight or pressure in pounds on the bucket by P, then

$$P = D^2 \times \cdot 7854 \times H \times 62 \cdot 42 \text{ lbs.}$$

This expression represents the useful effect of the pump, independent of the resistances due to the weight and friction of the pump-rod and bucket, and the friction of the water in the pipes. The height to which water can be raised is only limited by the power applied to work the pump.

Discharge of Pumps.—If the bucket of a single-acting pump is covered with water at each stroke to a depth of two-thirds the stroke; and D=the diameter of the pump-bucket in inches, L=the length of stroke in inches, and R=the number of the revolutions per minute of the crank-shaft :—

Then the capacity of the pump$=D^2 \times \cdot 7854 \times L$.

The quantity of water raised at each stroke$= D^2 \times \cdot 7854 \times L \times \frac{2}{3}$

The quantity of water raised in an hour $= D^2 \times \cdot 7854 \times L \times \frac{2}{3} \times R \times 60$ minutes.

The number of cubic feet of water raised per hour $= (D^2 \times \cdot 7854 \times L \times \frac{2}{3} \times R \times 60) \div 1728$.

Work of Pumps.—The maximum quantity of water in gallons per hour, G, which can be raised by an efficient double-acting force-and-lift pump may be found by this formula: $G=C \div L$. In which L=the height of the lift in feet, and $C=18,000$ when the pump is worked by one man working a crank: $C=36,000$ when worked by gear driven by a donkey: $C=120,000$ when worked by gear driven by a horse: and $C=190,000$ for each indicated horse-power when driven by a steam-engine.

Lifting Pumps.—The simplest kind of a pump for raising water is termed a lifting-pump, and in construction consists of a working-barrel, in which a bucket works, fitted with suction and delivery pipes. When the bucket moves upwards, a partial vacuum is formed under it, and water ascends into the barrel. The bucket is fitted with a flap-valve, which opens upwards to permit the water, which entered the barrel during the up-stroke, to pass through the bucket on its down-stroke. A valve-box and suction-pipe is fixed at the bottom of the barrel. This kind of pump is single-acting, it only discharges water on the ascent of the bucket, and consequently gives an intermittent discharge. The water is stopped and started at each stroke which produces shocks on the valves and pipes.

The effect of this percussive-action of the water may be alleviated by the employment of air-vessels, the capacity of which for high lifts should not be less than four times that of the pump, when placed on the delivery-side, nor less than twice that of the pump when placed on the suction side, of the pump.

Lift of Pumps.—When a pump lifts water it withdraws the pressure of the atmosphere from the surface of the water inside the suction-pipe, and the pressure of the atmosphere outside the suction-pipe forces up the water until the pressure inside and outside the suction-pipe become balanced. The distance the water is lifted is equal to the height of a column of water weighing 15 lbs. per square inch of area at its base, which is theoretically 34 feet; but, as it is impossible in practice to make perfect joints and prevent leakage of air, a perfect vacuum is never obtained, and 28 feet is the greatest distance above the level of the water from which a pump will lift water, although at that distance it will be liable to lose its water when the barometer is low. To prevent occasionally having a dry pump, the supply should never be drawn through a greater height than 25 feet; but, as the efficiency of a pump varies with the distance it lifts the water, the suction-pipe should be made as short as possible, and 15 feet is the maximum safe distance above the level of the water for a pump to work well and uniformly and draw its proper quantity of water at each stroke; but if the pump works quickly, better results will

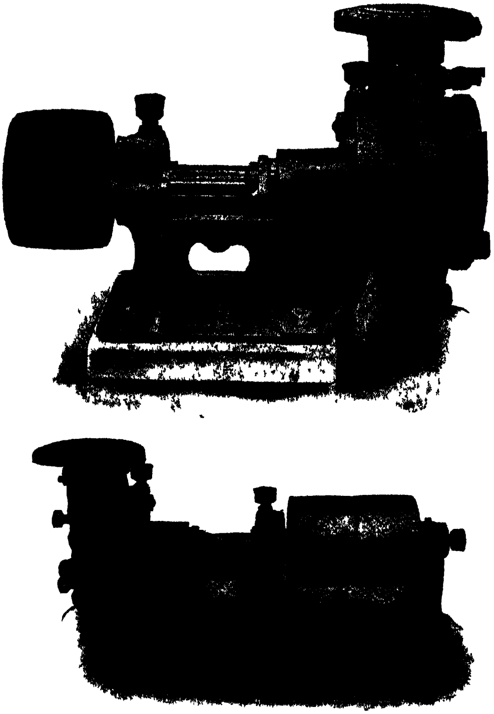


Fig. 81.—Ruston Pumps with Fast and Fast and Loose Pulleys.

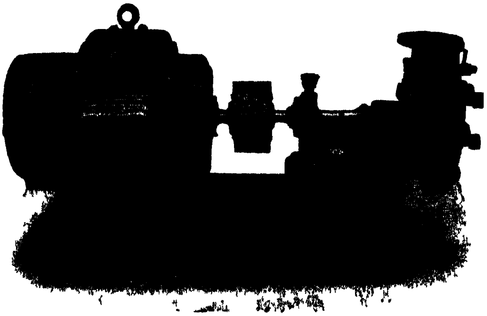


Fig. 82.—Ruston Pump direct coupled to Motor.

be obtained by making the distance 10 feet. The quicker the speed of the pump, the shorter should the suction-pipe be. A low-speed of bucket conduces to high efficiency. The speed of the bucket of ordinary pumps varies in practice from 40 to 160 feet per minute. The speed of deep-well pumps should not exceed 70 feet per minute, as the greater the speed and the higher the lift the more severe the concussion and wear of the valves.

Lifting and Forcing Pumps.—A combined pump is somewhat similar to a simple lifting pump. The bucket is fitted with an india-rubber valve, and is attached to a ram having a sectional area equal to one-half that of the working-barrel. At each up-stroke of the bucket the quantity of water which rises into the working-barrel is theoretically equal to that due to the length of barrel through which the bucket ascends, one-half of which quantity rises in the delivery pipe, or rising-main, on the descent of the bucket, and the remainder is discharged during the subsequent ascent of the bucket. Hence, the discharge from the pump is practically uniform and continuous. For high lifts annular metal-valves are generally used instead of india-rubber.

Pump-Valves.—The simplest form of a valve for a pump is a flap-valve or clack of leather, stiffened and weighted with metal plates, working on a hinge, as shown in Fig. 83. A leather-faced disc-valve, which slides up a spindle in lifting is shown in Fig. 84. The collar at the top of the spindle, for controlling the lift of the valve, may be loose and secured with a cotter to facilitate repairs. Teague's valve is a leather-faced clack, hinged upon another clack at the edge opposite to the main hinge, as shown in Figs. 85 and 86. A gun-metal mitre-faced valve is shown in Fig. 87. The wings of the valve are placed at an angle, to cause it to partly rotate and change its position on the seat at each beat, and induce uniform wear of the face and seat. India-rubber rings are placed upon the spindle to assist the closing of the valve. The plates between the rings should either be larger than the rings, or have a round bead on the edge to prevent the rings working over the plates. An india-rubber disc-valve is shown in Fig. 88. Soft india-rubber is the best for cold water, and hard india-rubber for hot water.

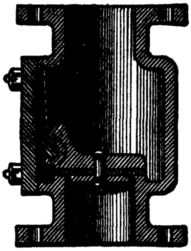


Fig. 83.—Flap-Valve.

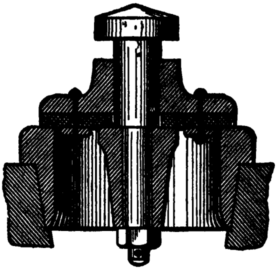
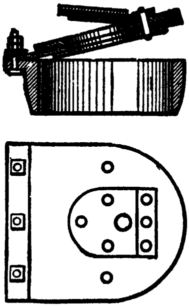


Fig. 84.—Disc-Valve.


Figs. 85 & 86.—Teague's-Valve.

The valves wear more uniformly when the grids are formed at an angle, as shown in Fig. 89, as the water moves the valve a little way round each time it is lifted. Vulcanised-fibre is a good and durable material for disc-valves. An annular-valve is shown in Fig. 90. The valve slides up a spindle in lifting; and in closing it is assisted by an india-rubber buffer-spring. A double-beat valve is shown at Fig. 91; the valve in lifting presents two openings for discharge, so that only one-half the lift is required than is necessary for a valve of the same diameter with a single opening.

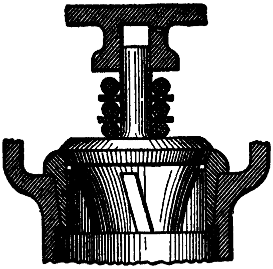


Fig. 87.—Mitre-Valve.

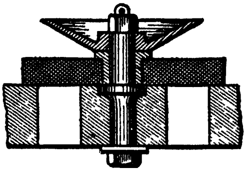


Fig. 88.—India-rubber Disc-Valve.

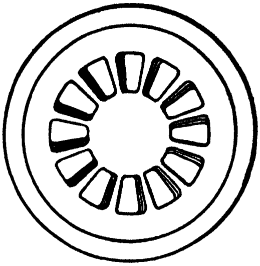


Fig. 89.—Plan of the Seating of Disc-Valve.

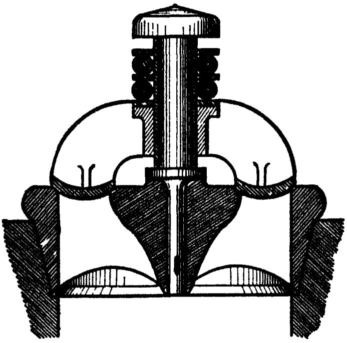


Fig. 90.—Annular-Valve.

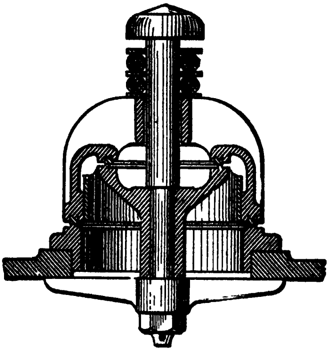


Fig. 91.—Double-Beat Valve.

To minimise the shocks due to the pressure of a great body of water above a valve, the seat is frequently formed of wood, either lignum-vitæ or holly. In some cases india-rubber cord is inserted in grooves in the seat of the valve, to prevent leakage and shocks.

Load on a Hand-worked Pump.—In a common hand-pump, with lever-handle, the leverage is generally 6 to 1, and the resistance on the handle, exclusive of friction, is found by dividing the weight due to the column of water by 6, the leverage.

Load on a Hand-Power Lift-Pump, with Crank and Well-Frame.—The radius of the winch-handle of a well-frame is generally 16 inches, and the leverage is found by dividing the radius of the winch-handle by the throw of the crank (or half-stroke of pump). Thus a pump, with 8-inch stroke, and with 16 inches radius of winch-handle, would have a leverage of 4 to 1, and the weight of the column of water it has to raise, divided by 4, will give the resistance to be overcome, exclusive of friction.

Load on Hand-Power Geared Well-Frames.—When gearing is applied to drive the crank of a well-frame, what is gained in power is lost in quantity in a given time. Thus, if a wheel and pinion of 2 to 1 are added to the above frame, only one-half the power will be required, but only one half the quantity of water will be raised at each turn of the handle.

To find the resistance in working a geared well-frame, divide the radius of the winch-handle by the throw of the crank (or half-stroke of pump), and multiply the result by the proportion of the wheel and pinion, and with the product divide the weight of the column of water, which will give the resistance to be overcome, exclusive of friction.

The power exerted by a man in turning the winch-handle of a pump may be reckoned at 20 lbs. In a single-barrel pump the whole lift comes at one half of the turn of the handle; but in a double-barrel pump it is distributed over the two halves of the turn; and in a treble-barrel pump the work is still more equalised. Therefore, it is easier to work a pump with two barrels than with one barrel, when the united capacity of the two barrels is the same as that of the single barrel.

Suction and Delivery-Pipes of Pumps.—The suction-pipe of a pump should always be larger than the delivery-pipe, because the friction has to be overcome in the suction-pipe by the pressure of the atmosphere only; but in the delivery-pipe the friction is overcome by the power of the pump. The suction and delivery pipes should never be less than one-half the diameter of the pump-barrel. A good proportion for the suction-pipe is two-thirds the diameter of barrel. In quick-working pumps it is sometimes necessary to make it as large as the barrel. A long suction-pipe should fall evenly along its length towards the well, as, if any portion of it is higher than the pump-end, a trap will be formed in which air will accumulate, and from which it cannot easily be drawn away. A long suction-pipe should have a retaining or foot-valve placed near the water to prevent it losing its water, and to obviate the charging of the suction-pipe at each stroke.

Pumps for Hot Water.—A pump will not lift hot water efficiently, because the steam destroys the vacuum; therefore the pump should be placed at the same level as the supply tank, so that the water may flow into the barrel by its own gravity. The valves of hot-water pumps should be made one-half larger in diameter than the ram, in order to obtain a large escape for the water with a small lift of the valve.

Force-Pump.—The barrel of a force-pump should be as close to the ram as possible, otherwise air will accumulate and impair the working of the pump. The diameter of the valves should never be less than three-fourths the diameter of the ram; but it is preferable to make them of the same diameter as the ram, which they should be placed as near to as convenient, and they should only lift sufficiently to deliver their full capacity of water.

An air-vessel should be placed on the delivery side of a pump—and also on the suction side of fast-moving pumps the air in which becomes compressed, and its elastic force causes the water to flow uniformly into the barrel, and ensures the barrel being properly and continuously filled at each stroke. The neck of the air-vessel should be long and narrow, to prevent the action of the pump disturbing its water-level. An air-vessel also greatly reduces the percussion and wear and tear of the valves.

Calculations for Pumps.—In addition to the weight of the water, allowance must be made for the friction of the pump and the friction of the water in the pipes, and also for the weight of the valves and for the resistance caused by the water passing through the valves, and likewise for the "slip," or water lost by the pump, as all pumps throw considerably less water than their capacity. In the following rules allowance is made for these contingencies.

Capacity of a Pump.—The capacity of a pump with piston or bucket is the product of the area of the barrel multiplied by the length of stroke, and the capacity of a pump with a ram is the product of the area of the end of the ram multiplied by the length of stroke.

Gallons of Water delivered per Stroke.—Multiply the square of the diameter in inches of the pump-bucket, or ram, by ·034, and by the length of the stroke in feet, and the product will be the number of gallons which the pump will deliver per stroke, provided the barrel gets properly filled with water at each stroke. But as all pumps throw considerably less than their capacity, deduct one-third from the number of gallons thus obtained for leakage, or "slip," and the remainder will be the actual quantity of water delivered per stroke, provided the pump is in first-rate order. But if the pump is of second-rate quality, it will be necessary to deduct one-half instead of one-third for "slip."

Actual Horse-power of Pumps.—Find the number of gallons per stroke by the above rule, and multiply it by 10 (the weight of a gallon of water), and by the number of strokes per minute. The product will be the weight of water lifted per minute, which multiply by the height in feet from the water to the point of delivery. The product will be the total work done per minute in foot-lbs. Divide by 21,780, then add $\frac{1}{8}$th for the friction of the engine itself, and the sum will be the actual horse-power of the engine required to drive that pump.

Nominal Horse-power of a Pump.—Find the total work done per minute, as in the last rule, and divide it by 32,670, then add $\frac{1}{8}$th for the friction of the engine itself. The product will be the nominal horse-power of the engine required to drive that pump.

In calculating the horse-power of deep-well pumps, the weight of the spears and spear-plates, rods, bucket, &c., must be added to the total work per minute before dividing by the above given divisor.

The effective work done by a pump is equal to the product of the weight of the water by the height it is raised, and the efficiency of that pump is the ratio of the effective work to the total work expended in driving it. In ordinary pumps the efficiency is about 66 per cent.

Diameter of Pump.—To find the diameter of a pump, multiply ·034 by the length of stroke in feet, then multiply by the number of strokes per minute, and divide the number of gallons to be delivered per minute by the said product. The square root of the quotient will be the diameter of the pump in inches; but as all pumps throw considerably less water than their capacity, add a third to the area of the pump, to allow for leakage or "slip;" this allowance for "slip" only applies to pumps in first-rate order; if the pump is of second-rate quality, it will be necessary to add one-half instead of one-third for slip.

The pumps illustrated in Figs 81 and 82 have been designed to give efficient and continuous service with the minimum attention and running costs. Ball bearings, renewable bronze rings to casing, gun metal glands and balanced impellers are fitted. The pumps are manufactured by Messrs Ruston & Hornsby, Lincoln, and are intended for heads up to 125 feet gross. Powers, speeds and outputs are given in Table 7.

Table 7.—Powers, Speeds and Outputs of Centrifugal Pumps

Size of Branches		British Gallons per Minute	GROSS HEAD, including Pipe Friction, in Feet.											
			70		75		80		85		90		95	
Dvry	Sctn		RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
Ins	Ins													
1½	2	20	2112	1 49										
		30	2142	1 73	2215	1 87	228[illegible]	2 02	2352	2 23	2418	2 35	[illegible]480	2 16
		40	2175	2 0	2240	2 1[illegible]	2310	2 3	[illegible]380	2 52	2447	7	510	57
		50	2215	2 3	2[illegible]0	2 51	235[illegible]	2 68	24[illegible]0	2 87	2485	3 1	[illegible]	2 31
		60	[illegible]50	2 66	2350	[illegible] 86	410	3 05	2475	3 3	2 3[illegible]	3 45	[illegible] 5	3 75
		70	**2350**	**3 11**	2410	3 33	475	3 15	2528	3 77	[illegible]00	[illegible]	[illegible]50	[illegible]
		80	2416	3 45	**2480**	**3 8**	**2546**	**4 05**	**2602**	**4 31**	**2670**	**4 56**	**2722**	**4 81**

Size of Branches		British Gallons per Minute	GROSS HEAD, including Pipe Friction, in Feet											
			100		105		110		115		120		125	
Dvry	Sctn		RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
Ins	Ins													
1½	2	20												
		30	2545	2 64	2600	2 88								
		40	2572	3 1	2625	3 26	2686	3 46	2746	3 6	2800	3 85	2855	4 02
		50	2600	3 45	2660	3 7	27[illegible]0	4 0	2777	4 17	2830	4 1	2885	4 55
		60	2650	3 95	2710	4 2	2770	4 38	28[illegible]	4 6	2877	4 8[illegible]	29[illegible]6	5 05
		70	2710	4 45	2775	4 61	2820	4 9	2880	5 17	29[illegible]7	5 15	2[illegible]86	5 62
		80	**2780**	**5 07**	**2840**	**5 17**	**2890**	**5 58**	**2946**	**5 75**	**3000**	**6 07**		

Hydraulic Ram.—This useful self-acting apparatus is used when there is a good flow of water with a moderate fall, to raise a small portion of that flow to a greater height than the fall. About 10 gallons of water must pass through the ram for every gallon raised, and the elevation to which water can be raised by the ram is in proportion to the fall obtainable, generally equal to ten times the fall.

The following are the usual proportions of the supply pipes and delivery pipes to the number of gallons.

Number of Gallons to be raised in 24 Hours	500	1000	2500	4000	6000
Diameter of Fall or Supply Pipe in Inches	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	4
Diameter of Rising Main or Delivery Pipe in Inches	$\frac{3}{4}$	1	$1\frac{1}{2}$	2	2

The efficiency of hydraulic rams rapidly decreases, as the height to which the water is to be raised increases above the fall. as will be seen from the following table.

TABLE 8.—EFFICIENCY OF HYDRAULIC RAMS.

Number of times the height to which the Water is to be raised contains the fall . .	4	5	6	7	8	9	10	11	12	13	14	15	16	18	19	20	25
Efficiency per cent. .	75	72	68	62	57	53	48	43	38	35	32	28	23	17	15	12	0

Speed of Pumps.—The greatest speed at which water will flow through a suction-pipe, is 500 feet per minute; but, in practice, water should not flow through a suction-pipe at a greater speed than 200 feet per minute to ensure the pump-barrel being properly filled at each stroke, that is 200 feet of the suction-pipe should hold as much water as the pump will deliver per minute, and the pump should work at such a speed that it will deliver per minute the quantity of water contained in 200 feet of its suction-pipe. For pumping engines, the most economical speed is from 4 to 5 strokes per minute, the length of stroke being generally 8 feet for small pumping engines; 10 feet for medium size; and 12 feet for large sizes.

Proportion of Cocks.—D = the internal diameter of pipe. Square of plug = D × ·5. Height of square = D × ·5. Length of handle = D × 6. Diameter of plug at the centre = D × 1·25. Length of taper part of plug = D × 2 to $2\frac{1}{2}$ for solid bottom gland cocks, and D × 3 to $3\frac{1}{2}$ for plugs with screw bottom. Height of water-way in plug = D × 1·25. Width of water-way in plug = D × ·7. Taper of plug on each side = 1 inch in 9 inches for small cocks, and 1 inch in 12 inches for large cocks.

TABLE 9.—SHEWING THE WEIGHT OF A COLUMN OF WATER, OR THE LOAD TO BE OVERCOME IN PUMP-BARRELS, EXCLUSIVE OF THE FRICTION IN THE PIPES.

Perpendicular Height from Bottom.	DIAMETER OF PUMP BARREL IN INCHES.															
	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7	8	9	10	12
Feet.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	bs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
10	8	14	22	32	42	55	69	85	103	123	144	167	218	276	341	492
20	16	28	43	62	84	109	138	170	206	246	288	333	436	552	680	980
30	23	42	64	92	125	164	207	255	308	368	432	499	653	826	1020	1469
40	32	55	85	124	167	218	276	340	412	492	575	666	872	1102	1360	1958
50	39	68	106	153	208	272	345	425	515	614	719	832	1088	1377	1700	2448
60	46	82	128	184	250	327	413	510	617	736	862	998	1306	1652	2040	2937
70	54	96	149	215	292	382	482	595	720	859	1006	1164	1524	1928	2380	3427
80	62	109	170	246	333	436	552	680	823	982	1149	1332	1742	2203	2720	3916
90	69	123	192	276	375	490	620	765	926	1104	1293	1497	1958	2478	3060	4406
100	77	136	212	306	416	544	689	850	1029	1227	1436	1663	2176	2754	3400	4895
110	85	150	233	338	458	599	758	935	1132	1349	1580	1829	2393	3029	3740	5385
120	92	164	255	368	500	653	826	1020	1234	1472	1724	1996	2612	3304	4079	5874
130	99	177	276	398	542	707	895	1105	1337	1595	1867	2162	2829	3580	4419	6364
140	107	192	297	429	583	762	964	1190	1440	1717	2012	2328	3046	3855	4759	6853
150	115	204	318	459	624	816	1033	1275	1543	1840	2155	2495	3264	4130	5099	7343
160	124	218	340	490	666	870	1102	1360	1646	1963	2298	2662	3482	4406	5439	7832
170	130	232	362	520	707	925	1172	1445	1748	2085	2442	2827	3699	4681	5779	8322
180	138	245	383	552	749	979	1239	1530	1852	2208	2585	2993	3916	4956	6119	8812
190	146	259	404	582	792	1034	1308	1615	1954	2331	2729	3160	4134	5232	6459	9301
200	153	272	426	612	832	1089	1378	1700	2057	2453	2874	3326	4352	5508	6800	9792

TABLE 10.—SHEWING THE QUANTITY OF WATER DISCHARGED PER MINUTE BY SINGLE-, DOUBLE-, AND TREBLE-BARREL PUMPS AT VARIOUS SPEEDS, EXCLUSIVE OF SLIP.

Diameter of Pump.	Length of Stroke.	SINGLE BARREL.		DOUBLE BARREL.		TREBLE BARREL.	
		30 Strokes per Minute.	40 Strokes per Minute.	30 Strokes per Minute.	40 Strokes per Minute.	30 Strokes per Minute.	40 Strokes per Minute.
Inches.	Inches.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.	Gallons.
1½	9	1¾	2¼	3½	4½	4½	6¾
2	9	3	4	6	8	9	12
2½	9	4¾	6¼	9½	12	14	19
3	9	6¾	9	13¾	18	20	27
3½	9	9¼	12½	18¾	25	28	37
4	9	12¼	16	24½	32	36	48
4½	9	15½	20¾	32	42	46	62
5	9	19	25½	38	50	57	76
5½	9	23¼	32	46½	62	69	92
6	9	27½	37	55	73	82	110
2	10	3½	4½	6	9	10	13
2½	10	5¼	7	10	14	15	22
3	10	7½	10	15	20	22	30
3½	10	10½	13¾	20	27	32	42
4	10	13½	18	27	36	40	54
4½	10	17	23	34	45	52	68
5	10	22	28	42	56	63	84
5½	10	25½	34	51	68	77	102
6	10	30½	40	62	82	92	122
2	12	4	5	8	10	12	16
2½	12	6¼	8	12	17	19	25
3	12	9	12	18	24	27	36
3½	12	12½	16	24	33	37	50
4	12	16¼	22	32	43	49	65
4½	12	20½	27	42	55	62	82
5	12	25¼	33	50	68	76	100
5½	12	30¾	42	62	82	92	123
6	12	36½	49	73	97	110	146
6½	12	43	57	86	114	129	172
7	12	50	66	100	134	149	199
7½	12	57	76	114	152	171	229
8	12	65	87	130	174	195	262
9	12	82	110	165	220	246	330
10	12	102	134	202	268	303	404
12	12	146	195	294	390	440	588

The Rose at the bottom of the suction-pipe of a pump, for preventing the admission of small stones and rubbish, is generally either cylindrical, circular, or egg-shaped. The aggregate area of the perforations should be equal to from 2 to 4 times the area of the suction-pipe.

TABLE 11.—SHEWING THE QUANTITY OF WATER IN GALLONS DELIVERED AT EACH STROKE OF A PUMP.

Diameter of Pump.	Length of Stroke of the Pump in Inches.																				
	3	4	5	6	7	8	9	10	11	12	14	16	18	24	30	36	42	48	54	60	72
Inches.	Gall.	Gall.	Gall.	Gall.	Gall.	Gall.	Gall.	Gall.	Gall.	Gall.	Gall.	Gall.	Gall.	Gall.	Gall.	Gall.	Gall.	Gall.	Gall.	Gall.	Gall.
1	008	·011	·014	017	·02	022	·025	·028	·031	·034	·04	·045	·05	·068	·085	·102					
1¼	·013	017	·021	·026	03	035	·04	·044	·048	·053	·061	·07	·08	·106	·132	·160					
1½	019	·025	·031	038	·044	05	·057	·063	·07	·076	·09	·101	·114	·153	·191	·230					
1¾	·026	·034	·042	·052	06	·07	·078	·086	·095	·104	·121	·138	·156	·208	·260	·312					
2	·034	·044	·055	067	08	·09	·10	·113	·124	·135	·158	·181	·20	·272	·340	·407					
2¼	·043	·056	·070	·086	·10	·11	·13	·143	·157	·172	·20	·22	·25	·344	·430	·51					
2½	053	·070	·086	·10	·12	·14	·16	·17	·19	·21	·24	·28	·31	·424	·531	·637					
3	·076	·100	·125	·15	·17	·20	·22	·25	28	·30	·35	·4	·45	·611	·764	·917	1·06	1·22	1·37	1·52	1·83
3½				·20	·24	·27	·31	·34	·38	·41	·48	·55	·62	·832	1·04	1·25	1·45	1·66	1·87	2·08	2·50
4				·27	·31	·36	·40	·45	·50	·54	·63	·72	·81	1·09	1·36	1·63	1·90	2·17	2·44	2·72	3·26
4½				·34	·4	·45	·51	·57	·63	·68	·8	·91	1·0	1·37	1·72	2·06	2·40	2·75	3·09	3·44	4·12
5					·49	56	·63	·71	·77	·85	·92	1·13	1·27	1·70	2·12	2·55	2·97	3·40	3·82	4·25	5·10
6						81	·92	1·02	1·12	1·22	1·42	1·63	1·83	2·44	3·05	3·67	4·28	4·89	5·50	6·11	7·34
7							1·25	1·38	1·52	1·66	1·94	2·22	2·50	3·33	4·16	5·00	5·82	6·66	7·50	8·32	9·99
8								1·81	2·0	2·17	2·53	2·90	3·26	4·35	5·43	6·52	7·61	8·70	9·78	10·87	13·05
9									2·52	2·75	3·21	3·67	4·13	5·50	6·88	8·26	9·63	11·01	12·38	13·76	16·52
10										3·40	3·96	4·53	5·09	6·80	8·50	10·20	11·90	13·60	15·30	17·00	20·40
11											4·80	5·48	6·17	8·22	10·27	12·33	14·38	16·45	18·50	20·55	24·67
12												6·52	7·34	9·79	12·23	14·68	17·13	19·58	22·02	24·47	29·37
13													8·61	11·49	14·36	17·23	20·10	22·98	25·85	28·72	34·47
14													10·0	13·32	16·65	19·98	23·31	26·65	29·97	33·31	39·97
15													11·5	15·29	19·11	22·94	26·76	30·59	34·41	38·23	45·89
16													13·0	17·40	21·76	26·11	30·46	34·80	39·16	43·51	52·22
17													14·7	19·65	24·56	29·47	34·38	39·30	44·21	49·12	58·94
18													16·5	22·02	27·53	33·04	38·54	44·05	49·55	55·06	66·08
19													18·4	24·54	30·67	36·81	42·94	49·08	55·21	61·35	73·62
20													20·4	27·19	33·98	40·79	47·59	54·39	61·18	67·98	81·58
22													24·6	32·90	41·13	49·36	57·58	65·81	74·03	82·25	98·72
24													29·3	39·16	48·95	58·74	68·53	78·32	88·10	97·90	117·47

The Strength of Steam-Cylinders, Water-Cylinders, pipes, and tubes of all kinds subject to internal pressure, may be found by the following rules. In the case of steam cylinders, allowance must be made for wear and for boring and re-boring.

Thickness of Metal for Pipes.—*Rule:* Multiply the working pressure inside the pipe in lbs. per square inch, by the internal radius of the pipe in inches, and divide the product by the safe working tension given in the table below for the material of which the pipe is made, to which quotient add the constant number C., and the result will be the thickness of the pipe in inches. The value of C. ranges from ·13 to 1·0, according to circumstances, for cast-iron pipes for water, C. is ·3; and for steam-pipes ·5, the working pressure in each case being taken at 133 lbs. per square inch, to allow for contingencies in making stock sizes of pipes.

Example: required the thickness of a cast-iron pipe 8 inches in diameter, suitable for a working head of 300 feet water-pressure, or 133 lbs. per square inch, then $= \frac{133 \text{ lbs. pressure} \times 4 \text{ (radius of pipe)}}{2500 \text{ safe working tension of cast-iron}} = \cdot 212 + \cdot 3$ $= \cdot 512$ inches thickness.

Bursting Pressure of Pipes.—*Rule:* Multiply the bursting tension in lbs. per square inch—given in the table below—of the metal of which the pipe is made, by the thickness of metal in inches, and divide the product by the internal radius of the pipe in inches, the result will be the bursting pressure in lbs. per square inch,

Example, required the bursting pressure of the 8-inch pipe given in the last example, then, $\frac{15000 \text{ bursting tension} \times \cdot 512 \text{ thickness of pipe}}{4 \text{ inches internal radius of pipe}} =$ 1920 lbs. bursting pressure.

TABLE 12.—STRENGTH OF MATERIALS FOR PIPES FOR THE ABOVE RULES

Material of which the Pipe, or Tube, or Cylinder is composed.	Bursting Tension in lbs.	Safe Working Tension in lbs.
Mild Bessemer-Steel	71680	11940
Phosphor-Bronze	56000	9330
Homogeneous Metal	56000	9330
Lowmoor or Best Yorkshire Iron	53760	8960
Solid-Drawn Wrought-Iron Tubes	49200	8200
Good Ordinary Wrought-Iron	47040	7840
Copper, Wrought	33600	5600
Best Bronze	33600	5600
Gun-Metal	31360	5200
Good Brass	18000	3000
Common Brass	16000	2670
Cast-Iron	15000	2500
Zinc	6720	1120
Lead	2240	370

CAST-IRON SOCKET-PIPES FOR WATER.

Pipes should be cast from good grey metal, twice run, of such quality that a bar of the same 2 inches deep × 1 inch thick placed upon supports 3 feet apart will not break with a less load than from 28 to 30 cwt. suspended at the centre, which weight will cause a deflection of about $\frac{3}{8}$ inch.

Strength of Metal.—The tenacity of the cast-iron of which pipes are usually made, averages 15000 lbs. per square inch, which divided by the factor of safety, 6, gives a working strength of 2500 lbs. per square inch.

Thickness of Metal of Pipes.—Besides making the thickness sufficient to bear the water pressure, allowance must be made for hydraulic shocks due to the closing of cocks, &c., as well as for the strain due to weights falling upon, or passing over them after they are laid underground; the following two rules are used by makers of water-pipes, both of which give good and nearly the same results.

Rule 1.—Multiply the internal diameter of the pipe in inches by the working head in feet, divide the product by 10,000, and add the constant number, ·30, to the result, which will give the thickness of metal (cast-iron) in inches.

Rule 2.—Multiply the working pressure in lbs. per square inch by the internal radius of the pipe in inches, and divide the product by the working strength of the metal 2500, then add the constant number ·30 to the result, which will give the thickness of the metal of the pipe in inches; this constant number is added for the allowance to be made for shocks, &c., mentioned above, and may be varied to suit circumstances.

The Depth of Socket is varied a little by different iron founders; a good proportion is to make the inside depth according to the following rule. Multiply the internal diameter of the pipe by ·13, and add the constant number 3 to the result. The space for the lead joint should be $\frac{5}{16}$ inch for small pipes, $\frac{3}{8}$ inch for medium-sized pipes, $\frac{1}{2}$ inch for large pipes, and $\frac{3}{4}$ inch for very large pipes.

Testing Pipes.—Pipes should be tested to double their working pressure—but not beyond that—otherwise the metal is liable to be strained and weakened; and, while under pressure, they should be struck moderately hard with a hammer to represent the shocks they will be subject to after being laid underground.

Deviation in thickness and weight.—A deviation in thickness of $\frac{1}{16}$ inch for small, and $\frac{1}{8}$ inch for medium sized, and $\frac{3}{16}$ for large sizes, is sometimes permitted, and a deviation in weight of about 1 lb. per inch in diameter is permitted.

Weight of Socket-Pipes.—The weights of ordinary sizes of pipes for water are given in Table 13.

The first two sizes are suitable for a working head of 100 feet water pressure, the 1½ to 9-inch pipes are suitable for 150 feet water-pressure, and the pipes above that size are suitable for a working head of 300 feet water-pressure—the proof strain being double these quantities.

TABLE 13.—WEIGHT OF ORDINARY SIZES OF CAST-IRON SOCKET-PIPES.

Internal Diameter in Inches.	Length of Pipe, exclusive of Socket.	Thickness of Metal in Inches.	Average Weight of Pipe.			Internal Diameter in Inches.	Length of Pipe, exclusive of Socket.	Thickness of Metal in Inches	Average Weight of Pipe.		
	Feet.		cwt.	qr.	lb.		Feet.		cwt.	qr.	lb.
$\frac{3}{4}$	$4\frac{1}{2}$	$\frac{7}{32}$	0	0	16	10	9	$\frac{9}{16}$	5	0	0
1	6	$\frac{1}{4}$	0	0	24	11	9	$\frac{9}{16}$	5	2	4
$1\frac{1}{4}$	6	$\frac{1}{4}$	0	1	0	12	9	$\frac{5}{8}$	6	2	10
$1\frac{1}{2}$	6	$\frac{1}{4}$	0	1	4	13	9	$\frac{5}{8}$	7	0	6
$1\frac{3}{4}$	6	$\frac{9}{32}$	0	1	10	14	9	$\frac{11}{16}$	8	1	24
2	6	$\frac{9}{32}$	0	1	15	15	9	$\frac{11}{16}$	9	0	22
$2\frac{1}{4}$	6	$\frac{9}{32}$	0	1	21	16	9	$\frac{3}{4}$	10	2	0
$2\frac{1}{2}$	6	$\frac{5}{16}$	0	2	1	18	9	$\frac{13}{16}$	13	2	21
3	9	$\frac{5}{16}$	0	3	22	20	9	$\frac{7}{8}$	15	1	18
$3\frac{1}{2}$	9	$\frac{5}{16}$	1	0	16	21	9	$\frac{7}{8}$	16	1	0
4	9	$\frac{11}{32}$	1	1	16	24	9	1	18	2	14
$4\frac{1}{4}$	9	$\frac{11}{32}$	1	1	23	27	9	$1\frac{1}{16}$	25	2	4
$4\frac{1}{2}$	9	$\frac{11}{32}$	1	2	14	30	9	$1\frac{3}{16}$	31	2	16
5	9	$\frac{3}{8}$	1	3	15	33	9	$1\frac{1}{4}$	36	2	20
$5\frac{1}{2}$	9	$\frac{3}{8}$	2	1	0	36	9	$1\frac{3}{8}$	44	0	14
6	9	$\frac{3}{8}$	2	1	15	39	9	$1\frac{7}{16}$	50	1	0
7	9	$\frac{7}{16}$	2	3	15	42	9	$1\frac{9}{16}$	59	0	0
8	9	$\frac{1}{2}$	3	1	15	45	9	$1\frac{5}{8}$	66	0	10
9	9	$\frac{1}{2}$	4	0	0	48	9	$1\frac{3}{4}$	75	2	0

NOTE.—The Length does not include the Length of the Socket, but the Weight includes that of the Socket.

Table 14.—WEIGHT OF ORDINARY STOCK SIZES OF CAST-IRON FLANGE-PIPES FOR WATER, PROVED TO THE SAME WATER PRESSURE AS THE SOCKET PIPES GIVEN IN TABLE 13.

Size inside Diameter.	Length of Pipe.	Thickness of Metal.	Diameter of Flange.	Thickness of Flange.	Number of Bolts.	Diameter of Bolts.	Diameter of circle of Centre of Bolts.	Average Weight of Pipe.		
Inches.	Feet.	Inches.	Inches.	Inches.	Bolts.	Inches.	Inches.	cwt.	qr.	lb.
$1\frac{1}{2}$	6	$\frac{1}{4}$	$4\frac{3}{4}$	$\frac{1}{2}$	3	$\frac{3}{8}$	$3\frac{3}{8}$	0	1	6
$1\frac{3}{4}$	6	$\frac{9}{32}$	$5\frac{1}{2}$	$\frac{9}{16}$	3	$\frac{1}{2}$	4	0	1	16
2	6	$\frac{9}{32}$	$6\frac{1}{2}$	$\frac{9}{16}$	4	$\frac{1}{2}$	$4\frac{3}{4}$	0	1	18
$2\frac{1}{2}$	6	$\frac{5}{16}$	7	$\frac{5}{8}$	4	$\frac{1}{2}$	$5\frac{1}{2}$	0	2	13
3	9	$\frac{5}{16}$	$7\frac{1}{2}$	$\frac{11}{16}$	4	$\frac{5}{8}$	6	1	0	0
$3\frac{1}{2}$	9	$\frac{5}{16}$	$8\frac{1}{2}$	$\frac{11}{16}$	4	$\frac{5}{8}$	7	1	0	22
4	9	$\frac{11}{32}$	$9\frac{1}{2}$	$\frac{3}{4}$	4	$\frac{3}{4}$	$7\frac{3}{4}$	1	1	20
$4\frac{1}{2}$	9	$\frac{11}{32}$	10	$\frac{3}{4}$	4	$\frac{3}{4}$	$8\frac{1}{4}$	1	3	0
5	9	$\frac{3}{8}$	$10\frac{1}{2}$	$\frac{7}{8}$	4	$\frac{3}{4}$	$8\frac{3}{4}$	2	0	15
6	9	$\frac{3}{8}$	12	$\frac{7}{8}$	6	$\frac{3}{4}$	10	2	3	0
7	9	$\frac{7}{16}$	14	1	6	$\frac{3}{4}$	$11\frac{3}{4}$	3	0	23
8	9	$\frac{1}{2}$	15	1	6	$\frac{7}{8}$	$12\frac{3}{4}$	3	3	0
9	9	$\frac{1}{2}$	$16\frac{1}{2}$	$1\frac{1}{16}$	6	$\frac{7}{8}$	$14\frac{1}{4}$	4	2	20
10	9	$\frac{9}{16}$	$17\frac{1}{2}$	$1\frac{1}{8}$	6	$\frac{7}{8}$	$15\frac{1}{4}$	5	3	0
11	9	$\frac{9}{16}$	19	$1\frac{3}{16}$	6	1	$16\frac{3}{4}$	6	0	10
12	9	$\frac{5}{8}$	20	$1\frac{1}{4}$	6	1	$17\frac{3}{4}$	7	1	0

Table 15.—WEIGHT OF EXTRA STRONG CAST-IRON FLANGE-PIPES.

Size inside Diameter.	Length of Pipe.	Thickness of Metal.	Diameter of Flange.	Thickness of Flange.	Number of Bolts.	Diameter of Bolts.	Diameter of circle of Centre of Bolts.	Average Weight of Pipe.		
Inches.	Feet.	Inches.	Inches.	Inches.	Bolts.	Inches.	Inches.	cwt.	qr.	lb.
2	6	$\frac{3}{8}$	$6\frac{1}{2}$	$\frac{9}{16}$	4	$\frac{1}{2}$	$4\frac{3}{4}$	0	2	3
$2\frac{1}{2}$	6	$\frac{3}{8}$	7	$\frac{5}{8}$	4	$\frac{1}{2}$	$5\frac{1}{2}$	0	3	4
3	9	$\frac{3}{8}$	$7\frac{1}{2}$	$\frac{11}{16}$	4	$\frac{5}{8}$	6	1	0	10
$3\frac{1}{2}$	9	$\frac{7}{16}$	$8\frac{1}{2}$	$\frac{11}{16}$	4	$\frac{5}{8}$	7	1	2	8
4	9	$\frac{1}{2}$	$9\frac{1}{2}$	$\frac{3}{4}$	4	$\frac{3}{4}$	$7\frac{3}{4}$	1	3	6
5	9	$\frac{1}{2}$	$10\frac{1}{2}$	$\frac{7}{8}$	4	$\frac{3}{4}$	$8\frac{3}{4}$	2	1	15
6	9	$\frac{5}{8}$	12	$\frac{7}{8}$	6	$\frac{3}{4}$	10	3	2	5
7	9	$\frac{5}{8}$	14	1	6	$\frac{3}{4}$	$11\frac{3}{4}$	4	1	15
8	9	$\frac{3}{4}$	15	1	6	$\frac{7}{8}$	$12\frac{3}{4}$	5	2	10
9	9	$\frac{3}{4}$	$16\frac{1}{2}$	$1\frac{1}{16}$	6	$\frac{7}{8}$	$14\frac{1}{4}$	6	1	13
10	9	$\frac{3}{4}$	$17\frac{1}{2}$	$1\frac{1}{8}$	6	$\frac{7}{8}$	$15\frac{1}{4}$	7	0	0
11	9	$\frac{7}{8}$	19	$1\frac{3}{16}$	6	1	$16\frac{3}{4}$	9	0	0
12	9	$\frac{7}{8}$	20	$1\frac{1}{4}$	6	1	$17\frac{3}{4}$	9	3	8
13	9	$\frac{7}{8}$	21	$1\frac{1}{4}$	6	1	$18\frac{3}{4}$	10	2	0
14	9	$\frac{7}{8}$	22	$1\frac{1}{4}$	8	$1\frac{1}{8}$	$19\frac{3}{4}$	11	1	0
15	9	$\frac{7}{8}$	23	$1\frac{1}{4}$	8	$1\frac{1}{8}$	$20\frac{3}{4}$	12	1	0
16	9	$\frac{7}{8}$	$24\frac{1}{2}$	$1\frac{5}{16}$	8	$1\frac{1}{8}$	22	12	3	10

Weight of Pipes and Cylinders.—A simple rule to find the weight of pipes and cylinders of cast-iron is:—From the square of the outside diameter subtract the square of the inside diameter in inches, multiply the result by 7 and divide that product by 3, which will give the weight in lbs. approximately of one foot in length of the pipe. To find the exact weight, use 7·4 as a multiplier instead of 7 given above.

To find the weight of pipes and cylinders of other metals, multiply the result found by the above rule by 1·05 for wrought iron; 1·08 for steel; 1·2 for gun metal; 1·15 for brass; 1·21 for copper; 1·004 for tin; 1·56 for lead; and by ·988 for zinc.

Contents of Pipes.—To find the number of gallons contained in a circular pipe, multiply the square of the diameter in inches by ·034; the product will be the contents in gallons in a foot length of pipe.

To find the weight of water in lbs. in a circular pipe 1 foot long, square the diameter in inches and multiply the result by ·34.

To find the weight of water in lbs. in a pipe 3 feet long, square the diameter in inches.

Thickness of Cast-Iron Gas-Pipes.—The thickness of metal given in Table 13 for water pipes, is also suitable for gas pipes up to 6 inches diameter, but above that size, the thickness is too great for pipes for this purpose, and the correct thickness of metal for cast-iron gas-pipes may be obtained by multiplying the thickness given in that Table

by ·86 for cast-iron pipes of from 7 to 13 inches diameter.
·76 Do. Do. 14 to 20 Do.
·70 Do. of 21 inches diameter and upwards.

Table 16.—Shewing the Contents in Gallons and Weight in lbs. of Water in Pipes and Wells 1 foot in Depth.

Diameter in Inches.	Number of Gallons.	Weight in lbs.	Diameter in Feet.	Inches.	Number of Gallons.	Weight in lbs.
1	·034	·34	1	9	14·99	149·94
2	·13	1·36	1	10	16·45	164·56
3	·30	3·06	1	11	17·88	178·86
4	·54	5·44	2	0	19·58	195·84
5	·85	8·50	2	6	30·60	306·00
6	1·22	12·24	3	0	44·06	440·64
7	1·66	16·66	3	6	59·97	599·76
8	2·17	21·76	4	0	78·33	783·30
9	2·75	27·54	4	6	99·14	991·44
10	3·4	34·00	5	0	122·40	1224·00
11	4·11	41·14	6	0	176·25	1762·56
12	4·89	48·96	7	0	239·90	2399·04
13	5·74	57·46	8	0	313·34	3133·44
14	6·64	66·64	9	0	396·57	3965·76
15	7·65	76·50	10	0	489·60	4896·00
16	8·70	87·04	12	0	705·02	7050·24
17	9·82	98·26	15	0	1101·60	11016·00
18	11·01	110·16	18	0	1586·30	15863·04
19	12·27	122·74	20	0	1958·40	19584·00
20	13·60	136·00				

To find the pressure in lbs. per square inch of water in pipes, multiply the head of water in feet by ·433. The head of water in feet is equal to the pressure of water in lbs. per square inch multiplied by 2·31.

Table 17.—Shewing the Pressure in Pipes with Various Heads of Water at 62° Fahr.

Head of Water in Feet	Pressure per Square Inch in lbs.	Head of Water in Feet.	Pressure per Square Inch in lbs.	Head of Water in Feet	Pressure per Square Inch in lbs.	Head of Water in Feet	Pressure per Square Inch in lbs.
10	4·33	160	70·28	310	134·23	460	199·18
20	8·66	170	73·61	320	138·56	470	203·51
30	12·99	180	77·94	330	142·89	480	207·84
40	17·32	190	82·27	340	147·22	490	212·17
50	21·65	200	86·60	350	151·55	500	216·50
60	25·98	210	90·93	360	155·88	550	238·15
70	30·31	220	95·26	370	160·21	600	259·80
80	34·64	230	99·59	380	164·54	650	281·45
90	38·97	240	103·92	390	168·87	700	303·10
100	43·30	250	108·25	400	173·20	750	324·75
110	47·63	260	112·58	410	177·53	800	346·40
120	51·96	270	116·91	420	181·86	850	368·05
130	56·29	280	121·24	430	186·19	900	389·70
140	60·62	290	125·57	440	190·52	950	411·35
150	64·95	300	129·90	450	194·85	1000	433·00

Injectors for Feeding Boilers.—For the average temperature of feed and height of lift of ordinary injectors, the quantity of water delivered in gallons per hour by an ordinary injector feeding the boiler from whence its steam supply is derived, may be found by the following rule: Multiply the square of the diameter of the injector nozzle in millimetres by the square root of the pressure of the steam in lbs. per square inch, and multiply the product by the constant number 2.

WATER WHEELS.

The Driving Power of flowing water being gravity, the power exerted by a weight of water falling from a given height is equal to the product of the weight of water in lbs., and the height of the fall in feet. But, in driving a waterwheel, a percentage of the power is absorbed by friction, by overcoming the resistance of the waterwheel, and by the loss due to leakage. The efficiency or power given out varies from 30 to 75 per cent. of the power of the water, according to the class of waterwheel employed. A horse-power being 33,000 lbs. raised one foot high in a minute, or 550 foot lbs. per second, *the theoretical force in a fall of water* is found thus:—Multiply the weight of a cubic foot of water, 62·4 lbs., by the number of cubic feet falling per second; multiply that product by the height of the fall in feet, and divide the result by 550; the quotient will be the available theoretical horse power of that fall.

Overshot Water-wheels.—The water is generally laid on this class of wheel at a little below the top of the wheel from the side at which it approaches. The current of water being reversed in the pentrough, it is called a pitch-back wheel; diameter of wheel from 1 to 1⅓ the height of fall; speed of the circumference 4 to 5 feet per second; efficiency from 60 to 70 per cent. of the waterpower expended.

High-Breast Water-wheel.—The water is laid on to this class of wheel about 27° from the top; diameter of wheel 1½ times the height of the fall; speed of the circumference 5 feet per second; efficiency 75 per cent. of the waterpower expended.

Breast Water-wheel.—The water is laid on to this class of wheel a little below the level of its axis; diameter of wheel equal to about twice the height of fall; speed of the circumference from 5 to 6 feet per second; efficiency from 55 to 60 per cent. of the waterpower expended.

Undershot Water-wheels with radial floats are used when the fall is under 5 feet; diameter of wheel from 12 to 20 feet; speed of the circumference = ·50 of the velocity of the water; efficiency from 25 to 33 per cent. of the waterpower expended.

Paddle Water-wheel.—Wheels of this class are fixed on boats moored in an open current; diameter of wheel from 14 to 20 feet; speed of the circumference = ·50 of the velocity of the water; efficiency from 25 to 33 per cent. of the waterpower expended.

Modern undershot Water-wheels with curved floats are suitable for falls under 6 feet; diameter of wheel from 10 to 20 feet; speed of circumference from 8 to 12 feet per second; efficiency 55 per cent. of the water-power expended.

Diameter of the Journals or necks of cast-iron main shafts of water-wheels.—*Rule* to find: Multiply three times the width in feet of the water-wheel by its diameter in feet, and the cube root of the product will be the diameter in inches of the neck or journal. Example: required the diameter of the neck of a main shaft for a water-wheel of 15 feet wide and 20 feet in diameter; then $15 \times 3 \times 20 = 900$; and $\sqrt[3]{900} = 9{\cdot}65$ inches, diameter of neck.

Length of neck or journal = $1\frac{1}{2}$ times the diameter.

Horse-power of Water-wheels.—To find the effective power of a water-wheel.—*Rule:* Multiply the quantity of water expended in cubic feet per second by the effective height of the fall in feet, and divide the product by one of the following divisors:—viz., 11·7 for high breast water-wheels; 13 for overshot; 15 for breast; and 22 for undershot water-wheels. Example: required the effective horse-power of a high breast water-wheel requiring 20 cubic feet of water per second, the effective height of fall being 29 feet 3 inches; then, $\frac{20 \times 29{\cdot}25}{11{\cdot}7} = 50$ effective horse-power.

FLOW OF WATER.

Flow of Water through Orifices.—To find the velocity of the discharge in feet per second of water flowing from the side of the cistern. *Rule:* Multiply the square root of the height in feet from the centre of the orifice to the surface of the water by 8. To find the height in feet.—*Rule:* Divide the square of the velocity in feet per second by 64.

To find the quantity of water in cubic feet per second discharged through an orifice.—*Rule:* Multiply the area of the orifice in square feet by the number of seconds, and multiply the product by five times the square root of the height in feet from the centre of the orifice to the surface of the water.

To find the quantity of water in gallons per second discharged through an orifice.—*Rule:* Multiply the area of the orifice in square feet by the number of seconds, and multiply the product by 31·5 times the square root of the height in feet from the centre of the orifice to the surface of the water.

The above rules apply to the discharge from a hole cut in the side of a cistern. If a short pipe be fixed inside the cistern, the discharge will be diminished to the extent of one-fifth; if a short pipe, in length equal to 4 times its diameter, be fixed on the outside of the cistern, the quantity discharged will be increased to the extent of about one-third, the quantity slightly decreasing as the length of the pipe is increased beyond a length equal to 4 times the pipe's diameter until it reaches a length equal to sixty times the diameter, when the discharge equals that of a simple orifice.

Time required to fill a Cistern when a known quantity of water per hour is going in and a known quantity is flowing out of the cistern. Divide the contents in gallons of the cistern by the difference of the quantity going in and the quantity going out, and the quotient is the time in hours and parts that the cistern will take in filling.

Time required in seconds for a Cistern to empty itself.—Mr. Banks' *Rule* is: Multiply the square root of the height in feet of the surface of the water from the orifice, by the area of the falling water surface in square inches, and divide the result by 3·7 times the area of the orifice in square inches.

Flow of Water over Weirs.—To find flow: Multiply the square root of the depth in feet from the surface of the water to the bottom of the orifice, or top of dam, by the sectional area of the water passage in square feet and multiply the product by 3·4. The result will be the discharge in cubic feet per second.

Flow of Water in Open Streams.—The velocity of water in a stream or river is greatest near the surface at the centre of the stream, and less near the sides and at the bottom. The surface velocity may be ascertained by placing a thin wood float on the centre of the stream and noting the time it requires to pass a measured distance; then the mean velocity will be ·8 of the surface velocity. The available quantity of water in the stream may be found by this *Rule:* multiply the sectional area of the stream in square feet by the surface velocity in feet per second and multiply that product by ·8, the result will be the discharge in cubic feet per second.

The Hydraulic Mean Depth is the quotient of the sectional area of a stream or river, divided by its wet perimeter; in circular pipes running full, the hydraulic mean depth is one-fourth of the diameter of the pipe.

The Velocity and Discharge of Water through pipes and channels running wholly or partly filled, may be found approximately as follows. Multiply the hydraulic mean depth in feet, by twice the fall in feet per mile, and multiply the square root of the product by 55: the result is the mean velocity of the stream in feet per minute, which result multiplied by the sectional area in square feet, gives the volume or discharge in cubic feet per minute, and this product multiplied by 6·24 gives the number of gallons discharged per minute.

Loss of Head due to Friction.—The loss of head arising from the friction of the water against the sides of the pipe may be obtained from the following *Rule*: Multiply 2·25 times the length of the pipe in miles by the square of the velocity of the water in the pipe in feet per second, and divide the product by the diameter of the pipe in feet: the result will be head of water in feet required to balance the friction. The friction of water increases nearly as the square of its velocity. When calculating the diameter of a pipe for water supply, the quantity of water should be increased to the extent of from 33 to 50 per cent. to provide against the reduction of the flowing section due to encrustation.

Bends in Pipes.—The above rules apply to straight pipes only; as bends in a pipe diminish the velocity of a fluid equal to ·0039 times the sum of the sines of the several angles of inflection, sharp turns should be avoided. In the report on the supply of water to the Metropolis, it is stated that the time necessary for the discharge of a given quantity of water through a straight pipe being 1, the time for an equal quantity through a curve of 90° would be 1·11; with a right angle 1·57; two right angles would increase the time to 2·464; and two curved junctions to only 1·23.

The following rules for pipes are very convenient, as they make allowance for bends and other irregularities in pipes of considerable length; they are as follows:—

To find the Velocity in Feet per Second.—*Rule:* Multiply the diameter of the pipe in feet by the inclination of the pipe in feet per mile, divide the product by 2·3, and extract the square root of the result.

To find the Diameter of the Pipe in Feet.—*Rule:* Multiply the square of the velocity in feet per second by 2·3, and divide the product by the inclination of the pipe in feet per mile.

To find the Inclination of the Pipe in Feet per Mile, to be given to overcome friction.—*Rule:* Multiply the square of the velocity in feet per second by 2·3, and divide the product by the diameter of the pipe in feet.

FALL OR INCLINATION OF DRAINS, SEWERS, WATER CHANNELS AND RIVERS.

	Inch.		Feet.
Minimum inclination for drains for houses . .	1	in	12
,, ,, ,, land . . .	1	,,	16
,, ,, submain drains for houses .	1	,,	40
,, ,, main drains for houses . .	1	,,	100
Fall of mountain torrents	1	,,	150
,, ,, rivers with rapid current . . .	1	,,	230
,, ,, ,, strong current . .	1	,,	280
,, ordinary rivers with good current . . .	1	,,	340
,, ,, winding rivers, subject to inundations with slow current	1	,,	440
Fall of water channels, supply pipes to reservoirs and small canals	1	,,	480
Fall of large canals	1	,,	570
Very slow current, nearly approaching to stagnant water	1	,,	1000

Mill Race.—In order to prevent deposits and the growth of plants, the mean velocity of water in a mill race or water channel, should not be less than from 1 to 1½ feet per second.

Limits of Velocity.—To prevent injury to the bed and banks, the velocity of water in feet per minute in a channel should be proportioned to the tenacity of the soil:—in soft alluvial deposits, 25; in clayey beds, 40; in sandy and silty beds, 60; in gravelly beds, 120; in strong gravelly shingle, 180; in shingly beds, 240; in shingly and rocky beds, 300 to 400.

Velocity of Water.—The velocity in feet per second at which various substances are carried off:—river mud, ·3; gravel, fine, ·4; clay, ·5; gravel, coarse, ·6; yellow sand ·7; river sand, 1·0; gravel, size of beans, 1·2; shingle, small, 2·3; shingle, large, 2·6; angular stones, size of an egg, 3·0; rock, soft, 5·0; rock, seamy, 6·0; rock, hard, 10·0.

Turbines.—The following formulæ can be used for water turbines, but the principal formulæ will answer for any kind of turbine.

$$D = \frac{K\sqrt{h}}{n};\ D = \frac{a}{\cdot436\,r};\ n = \frac{K\sqrt{h}}{D};\ n = \frac{20\,K\,Q}{a\,D};\ r = \frac{a}{\cdot436\,D};\ r = \frac{46\,K\,Q}{D^2\,n};\ r = \frac{D}{5}\text{ to }\frac{D}{8};\ t = \frac{m}{10}$$

$$a = \frac{20\,Q}{\sqrt{h}};\ a = \frac{20\,K\,Q}{D\,n};\ a = \cdot436\,D\,r;\ a = m'rs;\ a' = mrs;\ a' = 98\,a;\ Q = \frac{a\sqrt{h}}{20};\ Q = \frac{a\,D\,n}{20\,K}$$

$$m = 5\sqrt{D};\ m'\,4\cdot5\sqrt{D};\ b = \frac{625\,D}{\sqrt{m}};\ C = \frac{78\,D}{\sqrt{m'}};\ s = \cdot86\,S;\ d = D + r + \sqrt[3]{l};\ d' = D + 2r;\ W = \frac{D^2\,h}{3}$$

$H = \cdot1134\,Q\,h$, natural effect of fall. $H = \frac{30\,Q^3}{a^4}$ $H = \frac{a\,h\sqrt{h}}{267\cdot5}$ } actual horse-power, 66 per cent. of the natural.

Where Q = cubic feet of water passed through the turbine per second; h = height of fall in feet; D = diameter in inches of circle of effort in the turbine; a = area in square inches of the conduit passage into the turbine wheel; b = depth in inches of turbine buckets; c = depth in inches of leading buckets; r = breadth of turbine buckets in inches; m = number of buckets in the turbine wheel; m' = number of leading buckets; n = number of revolutions of turbine per minute; S and s = height of conduit and discharge in inches; t = thickness of steel-plate buckets in 16ths of an inch: H = actual horse-power of the turbine; l = length in feet, and d the diameter in inches of conduit pipe; d' = the diameter in inches of the discharge pipe; W = hydraulic pressure on the turbine wheel bearing on the end of the shaft; $K = 950$.

MEMORANDA FOR CALCULATING FLOW OF WATER, &c.

Discharge in 24 hours divided by 1440=discharge per minute.

Discharge in cubic feet per minute multiplied by 9000=gallons per day of 24 hours.

Discharge in cubic feet per second multiplied by 2·2=cubic yards per minute.

Discharge in cubic feet per second multiplied by 6·24=gallons per second.

Discharge in cubic feet per second multiplied by 133=cubic yards per hour.

Discharge in cubic feet per second multiplied by 375 = gallons per minute.

Discharge in cubic feet per second multiplied by 2400 = tons per day of 24 hours.

Velocity in feet per second multiplied by ·68 = miles per hour.

Velocity in feet per second multiplied by 60 = feet per minute.

Velocity in feet per second multiplied by 20 = yards per minute.

Pressure of water in lbs. per square foot = head in feet multiplied by 62·32.

Head of water in feet = pressure of water in lbs. per square foot multiplied by ·016.

Discharge of Sewers.—The discharge of sewage pipes is less than that of water pipes, the flow being retarded by the rough surface of the pipes caused by deposit. The rules given above will apply to sewage pipes by using a constant of 2·8, instead of 2·3 used for water pipes.

Hydraulic Press.—To find the pressure on the ram of the press in tons.—*Rule:* Multiply the area in square inches, of the press ram, by the length of the pump handle, from the fulcrum to the point the force is applied, in feet, and multiply the product by the force in lbs. applied to the handle, and call the result A. Next multiply the area in square inches, of the pump-plunger, by the distance in feet, between the fulcrum and the centre of the pump-plunger, and multiply the product by 2240, and call the result B.; then divide the result A. by the result B., and the quotient will be the pressure in tons on the ram.

Thickness of Metal for Hydraulic Press Cylinders.—Cast-iron cylinders for hydraulic presses are generally made in thickness = to one-half the diameter of the ram for a working permanent strain of 2 tons per square inch. *The Rule for the bursting pressure of thick cylinders is:* —multiply the cohesive strength of the metal in tons per square inch by the thickness of metal in inches, and divide the result by the sum of the internal radius of the pipe, and the thickness of metal in inches. *For the thickness of metal it is:*—multiply the internal radius of the pipe in inches, by the internal bursting pressure in tons per square inch, and divide the product, by the quotient of the internal pressure, in tons per square inch of section, subtracted from the cohesive strength of the metal, in tons per square inch.

Example: A hydraulic-press cylinder of cast-iron 5 inches thick, with ram 10 inches diameter, cohesive strength of metal 7 tons, would burst with $\dfrac{7 \text{ tons} \times 5 \text{ inches thickness of metal}}{5 \text{ inch radius} + 5 \text{ inches thickness of metal}} = 3\frac{1}{2}$ tons. The bursting pressure should have by the last rule, a thickness of metal $\dfrac{5 \text{ inch radius} \times 3{\cdot}5 \text{ tons bursting pressure}}{3{\cdot}5 \text{ tons—7 tons cohesive strength of metal}} = 5$ inches. *The rule for finding the cohesive strength required for a given pressure is*—add the internal radius in inches of the pipe to the thickness of the metal in inches; multiply the result by the internal pressure in tons per square inch, and divide the product by the thickness of metal.

Taking the above example, the cohesive strength would be

$$\frac{5 \text{ in. rad.} + 5 \text{ in. thickness of metal} \times 3{\cdot}5 \text{ tons internal bursting pressure}}{5 \text{ inches thickness of metal}}$$

= 7 tons.

The Accumulator.—The accumulator is used for storing the pressure of water, for working hydraulic cranes and machines. It consists of a long cast-iron cylinder, fitted at the top with a stuffing box and gland, through which a solid ram works; at the bottom of the cylinder are two pipes, one of which is connected to a pump, and the other to a hydraulic machine. On the top of the ram a cross head is fixed, which supports an annular cylinder, loaded with scrap-iron. The pump forces water into the cylinder, which raises the ram, and so long as the ram is upheld, the pressure of the water in the cylinder, and pipes connected to it, will be determined by the area of the ram, and the load upon it.

To find the pressure in pounds per square inch on the water in an accumulator: *Rule*, add the weight in pounds of the ram to the weight in pounds of the cross head and weighted cylinder, and divide the sum by the area of the ram in square inches.

The usual working pressure of hydraulic cranes is 700 lbs. per square inch, and of other hydraulic machines from 1500 lbs. to 2000 lbs. per square inch.

Pipe Coverings.—The loss of heat and power by radiation of heat from steam pipes is considerable, but it may be reduced to a minimum by clothing the pipes with a good non-conducting material, such as hair felt, which—being light and fibrous—is a good confiner of air. Organic substances are good non-conductors, but they should be protected from charring by encasing the pipes with tin-plate, so as to form a $\frac{3}{8}$ inch air space round the pipe, the air in which makes an efficient insulator of heat.

Steam Saved by Non-Conducting Coverings for Steam Pipes, relatively to the bare pipes, Each composition being wrapped twice round with paper, with an outside cover of double wrapped canvas painted with two coats of paint. Total thickness of each covering 1$\frac{1}{2}$ inches.

	PER CENT		PER CENT.
Hair felt, wood lagged	96	Clay, sawdust, paper-pulp, flour	80
Slag wool, wrapped in felt	95	Flax fibre, clay, paper shavings, flour	79
Paper, hair felt	93	Moss, hair, sawdust, flour	79
Air space, hair felt	93	Thin hair felt, straw rope	78
Chopped straw, silicated	92	Chalk, hair, flour	78
Bran, silicated, thin felt	91	Charcoal, sawdust, hair, flour	76
Air space, bran, hair	90	Peat, sawdust, hair, flour	74
Fossil meal and hair plaster	89	Pumice stone, sawdust, clay, flour	74
Air space, fine wool	89	Ashes, hair, cement	72
Air space, fine cotton	87	Asbestos paste, paper	71
Air space, goat's hair	86	Brick dust, sand, flax, cement	70
Air space, paper-pulp, hair	84	Air space, tin-plate case, paper	69
Clay, hair, flour, flax fibre	84	Clay, flax refuse	69
Larch turnings, hair, flour	82	Asbestos paper, brown paper	68

SECTION III.

MILLWORK, SHAFTING, GEARING, PULLEYS, &c

SECTION III.

MILLWORK: SHAFTING, GEARING, PULLEYS, ETC.

TOOTHED WHEEL GEARING.

Wheel-Gearing.—Where motion has to be transmitted with precision, toothed wheel gearing must be used. The teeth should be so formed that the wheels will work together with the smallest amount of friction, and work smoothly and uniformly with a constantly equal power and with comparatively little noise, in the same manner as if two plain cylinders were rolling upon each other by the friction of their own pitch circles. As a wheel acts as a lever of a length represented by its radius, the leverage is governed by the diameter; but in making calculations, the number of teeth is used instead of the diameter. As fine-pitch wheels have a smoother and more uniform action than coarse ones, the pitch should always be made as fine as possible, consistent with the power transmitted. In calculating gearing, the diameter of the pitch-circle is taken as the diameter of the wheel, and when the wheels are properly in gear their pitch-circles meet and roll upon each other.

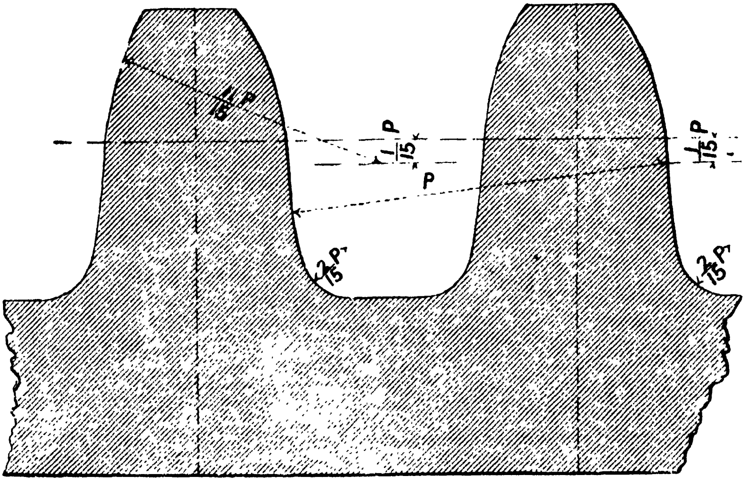


Fig. 92.—Method of Drawing the Teeth of Wheels.

Bevel and Mitre Wheels must be regarded as two cones rolling upon each other, and the teeth are drawn upon the same principle as those of spur wheels, the maximum pitch diameter being always taken as the diameter of bevel and mitre wheels.

Form of Teeth of Wheels.—The following simple method of forming the teeth of wheels gives good results. Teeth thus formed and wheels made to the following proportions work accurately and smoothly together, wear uniformly, maintain their shape, and make very little noise in working. The utmost strength being given to the roots of the teeth, the liability to breakage and wear and tear is reduced to a minimum, and all wheels of the same pitch work properly together.

When the flank—or side of the tooth below the pitch line—is curved, the radius of the flank equals the pitch of the tooth, and the point from which this radius is struck is $\frac{1}{15}$ part of the pitch in depth below the pitch line, as shown at Fig. 92.

The radius of the point or face of the tooth,—or that portion of the tooth above the pitch circle,—equals $\frac{9}{15}$ the pitch for wheels with less than 21 teeth, and $\frac{11}{15}$ the pitch for wheels with upwards of 20 teeth. The point from which each radius is struck, is $\frac{1}{15}$ part of the pitch in depth, below the pitch line; the radius of the curve at the root of the tooth is $\frac{2}{15}$ the pitch. The flank of the tooth may also be made flat or parallel, and joined to the rim with a curve at the root of the tooth having a radius of $\frac{2}{15}$ the pitch, for wheels with more than 20 teeth; but for wheels with flat flanks with less than 21 teeth, the flanks should radiate towards the wheel centre, and the roots of the teeth should join the rim with a small curve.

Proportions of the Teeth of Iron and Steel Wheel-Gearing.—A simple method of drawing the teeth of wheel-gearing is clearly shown in Fig. 92. The pitch is divided into 15 equal parts, and the teeth are formed to the following proportions:—

From the pitch line of the wheel to the top of the tooth = 5 parts.
From the pitch line of the wheel to the bottom of the tooth = 6 parts.
Thickness of the tooth at the pitch line = 7 parts.
Space between the teeth at the pitch line = 8 parts.
Thickness of the rim = 7 parts.
Depth of feather or rib under the rim = 8 parts.
Thickness of feather or rib under the rim = 7 parts.
Thickness of the arm = 7 parts.
Thickness of the feather or rib on the arm = 4 parts.
Depth of the feather or rib on the arm = 3 parts.
Diameter of the boss = twice the diameter of the shaft.
Depth of the boss = $1\frac{1}{4}$ times the width of face of the wheel.
Depth of the feather or rib round the boss = 8 parts.
Thickness of the feather or rib round the boss = 7 parts.
Radius of curve at the root of the tooth = 2 parts, as shown in Fig. 92.
Radius of the point or face of the tooth of wheels with upwards of 20

teeth = 11 parts. Radius of the point or face of the tooth of wheels with less than 21 teeth = 9 parts. Point below the pitch line of the wheel, from which the radius of the point or face of the tooth is struck = 1 part.

Breadth of the arm at the rim = $1\frac{3}{4}$ the pitch of the teeth, when the wheel face does not exceed $2\frac{1}{4}$ times the pitch in width; and = 2 times the pitch for widths of face from $2\frac{1}{2}$ to 3 times the pitch; and = 3 times the pitch for width of face equal to 4 times the pitch.

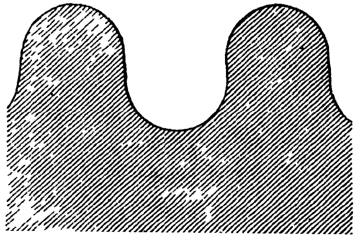


Fig. 93.—Knuckle gear

Breadth of the arm at the boss, should be increased by tapering the arm down from the rim to the boss, at the rate of $\frac{1}{4}$ inch per foot, on each side of the arm. The tendency of the strain being to twist the arm, the power acts with the greatest effect near the boss.

The teeth of wheels above 4 inches pitch may be shorter than given above—say $4\frac{1}{2}$ parts from the pitch line to the top of the teeth, and $5\frac{1}{2}$ parts from the pitch line to the bottom of the tooth = a total depth of tooth of $\frac{10}{15}$ the pitch.

The Maximum Working-Speed of Toothed-Wheels at the pitch-line, in feet per minute, consistent with freedom from excessive wear and tear, is—

Cast-Iron Wheels, with straight teeth	1,800 feet
Cast Steel ,, ,, ,, ...	2,100 ,,
Mortice-Wheels, wood-teeth	2,200 ,,
Cast-Iron Wheels, with double helical teeth . . .	2,300 ,,
Cast-Steel Wheels, ,, ,, ,, . . .	2,400 ,,
Worm-Wheels of Iron or Steel	270 ,,

Fig. 93 shows a form of tooth used for crab-wheels, called knuckle gear.

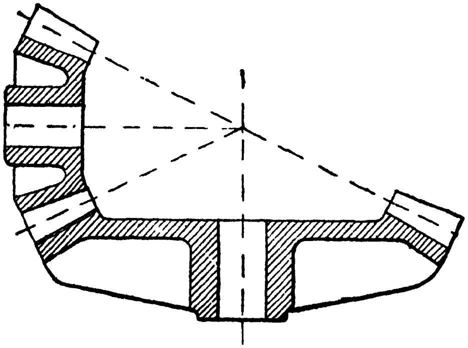


Fig. 94.—Bevel-Wheels.

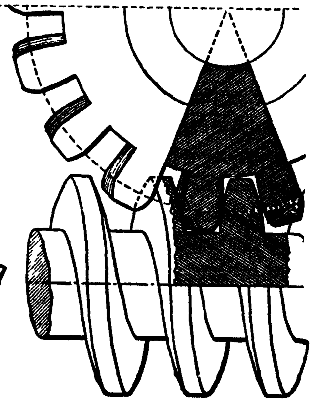


Fig. 95.—Worm and Worm-Wheel.

Fig. 94 shows the way to project a pair of bevel-wheels, with their shafts at right angles.

The delineation of a worm and worm-wheel is shown in Fig. 95.

Fig. 96 shows the way to project a pair of angle wheels, or bevel wheels with their shafts at an angle of 65°.

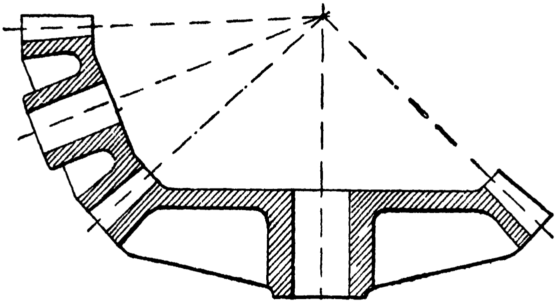
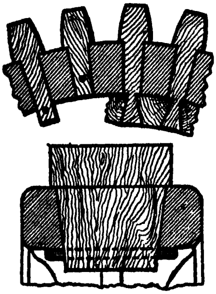


Fig. 96.—Bevel Wheels



Figs. 97 & 98.—Mortice-Wheel-Teeth.

Number of Arms.—Wheels under 2 feet diameter should have 4 arms, wheels from 2 to 7 feet 6 inches diameter, 6 arms; wheels from 8 to 12 feet, 8 arms; and wheels from 13 to 16 feet diameter, 10 arms.

Width of Face.—The least width of face necessary to resist the full transverse strain on the tooth is $1\frac{1}{2}$ times the pitch, but for the sake of durability the width should not be less than 2 times the pitch; $2\frac{1}{2}$ times the pitch is the usual width. The following are good proportions:—

Pitch of wheel, in inches . .	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	4
Width of face of wheel, in inches	2	$2\frac{1}{4}$	$2\frac{1}{2}$	3	$3\frac{1}{2}$	$3\frac{3}{4}$	4	$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	7	8	9	10	11	12	15

Mortice Wheels.—The wood teeth of a mortice wheel are made thicker than the teeth of its iron fellow, to compensate for the difference in strength of the material; consequently the thickness of the iron tooth has to be reduced, and the length of tooth is also reduced so as to be in proportion to the thickness. A wood-cog is shown in Fig. 99.

Thickness of wood cog = 9 parts, or $\frac{9}{16}$ of the pitch.
Thickness of tooth of iron wheel or fellow = 6 parts.
From the pitch line to the top of tooth = 4 parts.
From the pitch line to the bottom of the tooth = 5 parts.
Thickness of the rim = the pitch of the teeth multiplied by 1·2.

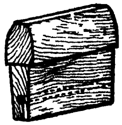


Fig. 99.—Wood Cog.

Width of face of wheel same as for spur and bevel wheels given above.

Width of mortice or shank of wood cog = $\frac{1}{2}$ inch narrower than the face of the tooth. Methods of fixing wood-cogs are shown in Figs. 97 & 98.

Thickness of metal at each end of mortice = $6\frac{1}{2}$ parts.

No clearance is required: the wood cogs should be trimmed to fit accurately between the iron teeth.

When a pair of wheels of large diameter and quick speed work together, the larger one should have wood teeth, and the smaller one iron teeth. Wood teeth wear out sooner, but are not more liable to break than iron teeth. Beech, oak, and maple are sometimes used, but horn-beam, iron-wood, and crab-tree are the best woods, for making the cogs. When working they should be smeared with a mixture of soft soap and plumbago.

Worm-Wheels.—When the shafts are at right angles, the action of a worm and worm-wheel is similar to that of a rack and pinion, and the formation of the teeth at the section at the centre of a worm-wheel, should be the same as those of a spur-wheel of the same diameter, and the section of the thread of the worm should be the same as the teeth of a rack of the same pitch of tooth. Each revolution of the worm, turns the worm-wheel, to the extent of one tooth with a single thread worm, and 2 teeth with a double thread worm. The teeth of worm-wheels are made shorter than spur wheels. The amount the teeth are angled or skewed is equal to the pitch of the teeth. A worm and worm-wheel are shown in Fig. 95.

Thickness of tooth = 7 parts, or $\frac{7}{15}$ of the pitch.
Space between the teeth = 8 parts.
From the pitch line to the top of the tooth = $4\frac{1}{2}$ parts.
From the pitch line to the bottom of the tooth = $5\frac{1}{2}$ parts.
Radius of the point or face of the tooth = 9 parts.
Flank of tooth, straight and flat.
Width of face of tooth = $1\frac{1}{2}$ times the pitch.
External diameter of worm = 4 times the pitch.

Pitch of Small Wheels.—The pitch of change wheels and other small wheels, is reckoned on the diameter of the pitch circle of the wheel instead of the circumference, and it is called the pitch per inch.

To find the number of teeth, in a wheel of a given diameter and pitch per inch:—

Multiply the diameter of the pitch circle in inches, by the given pitch per inch.

To find the diameter of the pitch circle, to contain a given number of teeth of a given pitch per inch:—

Divide the number of teeth by the required pitch per inch.

TABLE 18.—PITCH PER INCH IN DIAMETER AND CIRCULAR PITCH COMPARED.

Pitch per Inch in Diameter.	Nearest Circular Pitch in Inches.	Pitch per Inch in Diameter.	Nearest Circular Pitch in Inches.
3	$1\frac{1}{32}$	9	$\frac{1}{4}$ and $\frac{3}{32}$
4	$\frac{3}{4}$ and $\frac{1}{32}$	10	$\frac{5}{16}$
5	$\frac{5}{8}$	12	$\frac{1}{4}$
6	$\frac{1}{2}$	14	$\frac{1}{8}$ and $\frac{3}{32}$
7	$\frac{7}{16}$	16	$\frac{3}{16}$
8	$\frac{3}{8}$	20	$\frac{1}{8}$ and $\frac{1}{32}$

The pitch per inch in diameter (Table 18), bears the same ratio to the circular pitch, as the diameter to the circumference, a diametral pitch of 1 inch, corresponds with a circular pitch of 3·1416 inches; hence to find the circular pitch divide 3·1416 by the given diametral pitch, and to find the diametral pitch divide 3·1416 by the given circular pitch. The outside diameter of a wheel—over the top of the teeth—is found by adding two parts of the diametral pitch to the pitch diameter, for instance a wheel of 48 teeth, 8 per inch pitch, is 6 + $\frac{2}{8}$ths = 6¼ inches diameter outside. *The depth of tooth* of these small wheels is usually = $\frac{3}{4}$ths the pitch.

Angular and Circumferential Velocity of Wheels.—The angular velocity of a revolving body, is the velocity of a point at a unit's distance from the centre of motion, or the angle swept through in a second by a line perpendicular to the axis of motion, the angle being expressed in circular measure. Every point of a revolving wheel has a different velocity in proportion to its distance from the centre of motion, for instance in a revolving pulley, the boss will make the same number of revolutions as the rim, but the angular velocity of the rim will be greater than that of the boss.

To find the circumferential velocity of a wheel:—Multiply the circumference in feet by the number of revolutions per minute, the product will give the space passed through by any point of the circumference in feet per minute, which divided by 60 will give the velocity in feet per second.

To find the angular velocity of a wheel, or the number of revolutions made in a given time:—Divide the circumferential velocity per second, (found by the last rule) by the circumference in feet, the result will give the angular velocity, which multiplied by 60 will give the number of revolutions per minute.

The Centre of Gyration is a point in a revolving body in which the momentum, or energy of the moving mass, is supposed to be concentrated.

The radius of gyration of a fly-wheel (including arms and rim) and of gearing may be assumed in practice as the radius of the inside of the rim. To find the amount of force, to apply at the radius of a wheel, to cause it to make a certain number of revolutions, in a given number of seconds. *Rule:* multiply the number of revolutions by the weight of the wheel in lbs., and multiply the product by the square of the distance in feet from the centre of motion to the centre of gyration, and call the result A. Then multiply the constant number 153·5 by the number of seconds during which the force is applied, and multiply the product by the radius in feet on which the force acts, and call the result B.; lastly, divide the result A. by the result B., which will give the required force in lbs.

The Radius of Gyration of a solid wheel of uniform thickness, or of a circular plate, or of a solid cylinder of any length, revolving on its axis, is = to the radius of the object multiplied by ·7071.

SPEED OF GEARING.

The ratio of the numbers of teeth in a pair of wheels, must be the same as that of their diameters.

To find the speed of the driving wheel:—Multiply the number of teeth in the driven wheel, by the number of revolutions it makes per minute, and divide the product by the number of teeth in the driving wheel.

To find the speed of the driven wheel.—Multiply the number of teeth in the driving wheel, by the number of revolutions it makes per minute, and divide the product by the number of teeth in the driven wheel.

To find the final speed of a train of wheels.—Multiply the number of revolutions per minute of the first driving wheel, by the product of the number of teeth in the driving wheels, and divide the result by the product of the number of teeth in the driven wheels.

To find the number of teeth in the driving wheel.—Multiply the number of teeth in the driven wheel, by the number of revolutions it makes per minute, and divide the product by the number of revolutions of the driving wheel.

To find the number of teeth in the driven wheel.—Multiply the number of teeth in the driving wheel, by the number of revolutions it makes per minute, and divide the product by the number of revolutions of the driven wheel.

To find the relative numbers of teeth in a pair of wheels, when the speeds of the driving and driven shafts are given. Divide the speed of the driven shaft, by the speed of the driving shafts; the quotient is the ratio of their speeds; and the numbers of teeth in the wheels must be in the same ratio.

To find the diameters of a pair of wheels, the distance between the centres, and also the speed of each shaft being given. Multiply the speed of one shaft by the distance between the centres in inches, and divide the product by the sum of the speeds of the two shafts, the result will give the radius of one wheel, which doubled, will give its pitch diameter in inches. The radius of this wheel subtracted from the distance between the centres, will give the radius of the other wheel.

To find the pitch of a wheel.—Divide the diameter of the wheel at the pitch circle, by the number of teeth, and multiply the quotient by 3·1416.

To find the number of teeth in a wheel.—Divide 3·1416 by the pitch, and multiply the quotient, by the diameter of the pitch circle in inches.

To find the diameter of a wheel at the pitch circle.—Divide the pitch by 3·1416, and multiply the quotient by the number of teeth.

Wheels and Pinions.—A wheel should not have more teeth than 6 for 1 of its pinion. Large pinions are desirable, because when a large wheel drives a small pinion rapidly, the teeth of the pinion moving in a small circle, abruptly meet the teeth of the wheel, and cause an uneven jolting motion. When wheels drive pinions, no pinion should have less than 20 teeth, and in millwork not less than from 35 to 45 teeth, to enable them to work properly, and have a sufficient number of teeth in gear at the same time. When pinions drive wheels no pinion should have a less number than 13 teeth; rather 16 or 18. When quick speed is required instead of using a large wheel and very small pinion, it is better to get up the speed by using an intermediate shaft with wheel and pinion, and the friction will not be materially increased thereby.

The Minimum Friction of a Pair of Toothed-Wheels, exclusive of the friction of the shafts of the wheels, is frequently as follows:—

	Per cent.		Per cent.
Sprocket wheels and chain	1	Cast bevel wheels	5
Cut spur wheels	2	Sprocket wheels of motor cars	6
Cut bevel wheels	3	Double helical wheels	10
Cast spur wheel, hide pinion	3½	Single helical wheels	20
Cast spur wheels	4	Worm and worm-wheel	50

Power of Wheel Gearing.—The pressure on the teeth of wheels varies inversely as the number of revolutions and directly as the power transmitted. Thus, if the same power be transmitted by two wheels at different velocities, say one at 30 and the other at 120 revolutions, the strain on the former will be four times that of the latter; or if one wheel transmits 10 horse-power and another 20 horse-power at the same velocity, the strain on the latter will be double that of the former. Again, the power transmitted by a wheel depends upon the number of teeth in gear at one time and also upon its velocity.

Power of Spur Wheels.—The horse-power of the ordinary spur wheels used in machinery and millwork is given in table 19, which has been deduced from cases in practice. In cases where wheels are subject to unusually great strains they are made of other materials than cast iron.

Good Malleable Cast-Iron Wheels have double the strength of cast-iron wheels.

Good tough Gun-metal Wheels, have double the strength of cast-iron wheels.

Wrought-Iron Wheels, are three times as strong as cast-iron wheels, when made of best iron, with the grain of the iron in the direction of the circumference of the wheel.

Good Cast-Steel Wheels, are four times as strong as cast-iron wheels.

Shrouded Wheels, or wheels with two flanges, are from one-third to one-half stronger, according to the form of tooth, than plain wheels.

The Power of Bevel and Mitre Wheels may be taken from table 19, but instead of the maximum, the mean diameter and pitch must be taken; for instance, a bevel wheel 36 inches maximum diameter, with 6 inches face, has a minimum diameter of 30 inches, the mean diameter is therefore 33 inches, the pitch is 3 inches, but the minimum pitch is in proportion to the diameter; thus $\frac{3 \times 30}{36} = 2{\cdot}5$ minimum pitch, and the mean pitch will therefore be $\frac{3 + 2{\cdot}5}{2} = 2{\cdot}75$ mean pitch, and in looking for the horse-power in the table, it must be called 33 inches diameter × $2\frac{3}{4}$ inches pitch.

Power of Mortice-Wheels.—When running at a good speed, mortice-wheels are quite as strong as iron toothed wheels, but at a low speed they are weaker than iron wheels.

Power of Crane Gearing.—When wheels work at very low velocities lifting heavy weights, as in cranes, the safe working load should not exceed $\frac{1}{10}$ of the breaking weight, and the strength of the teeth should be calculated accordingly. A bar of good cast-iron 1 inch long, and 1 inch square, loaded at the end, will break with 6000 lbs., and the tooth of a wheel is similar to a beam loaded at one end and fixed at the other, hence the following rule:—

To find the Breaking Strain of each Tooth in a Wheel.—Multiply the square of the thickness of one tooth by its width, then by 6000, and divide the result by the length of tooth, the product will be the breaking weight in lbs. of each tooth.

Example: A crane to lift 4 tons, has a wheel 4 feet diameter, with a barrel 12 inches diameter, measuring to the centre of the chain. The pressure at the pitch-line of the wheel will be the weight to be lifted in lbs., multiplied by the diameter of the barrel in feet, and divided by the diameter of the wheel in feet: then $\frac{8960 \times 1}{4} = 2240$ lbs. actual strain, and suppose the teeth to be $\frac{3}{4}$ thick × $1\frac{1}{8}$ long × 4 inches wide, then $\frac{{\cdot}75^2 \times 4 \times 6000}{1{\cdot}125} = 12{,}000$ lbs. the breaking weight of one tooth, and if two teeth are in gear at the same time, the breaking strain of two teeth will be $12{,}000 \times 2 = 24{,}000$ lbs., the ratio of which to the actual strain is $\frac{24{,}000}{2240} = 10{\cdot}7$ to 1, which is ample for safety. Machinery subject to shocks from sudden change of speed and irregular strains, must have an excess of power in the gearing to provide against accidents. This rule for obtaining the actual strength of teeth applies to wheels working slowly and lifting heavy weights —the following rule is used for ordinary gearing.

Horse-Power of Gearing.—*To find the horse-power of ordinary iron-toothed spur wheels*, used in machinery and millwork. *Rule:* Multiply the square of the pitch of the teeth in inches, by the width of face of the teeth in inches, multiply the product by the diameter of the wheel in feet at the pitch circle, and multiply that product by the number of revolutions per minute, and divide the result by the constant number 240, the result will be the actual or indicated horse-power which that wheel will properly transmit.

CRANE GEARING.

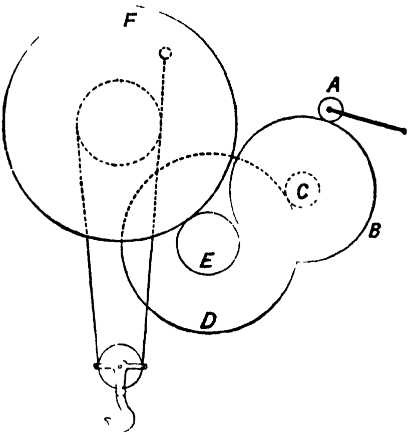


Fig. 100.—Crane-Gearing.

To find the strains at the pitch-lines of a train of wheels, such as the crane gearing shown at Fig. 100. The power exerted by a man at the handle of a crane, working continuously, is 15 lbs. at a velocity of 220 feet per minute; the strain at the handles worked by 4 men will be 15 × 4 = 60 lbs., and assuming the gearing to be as follows:—

1st pinion A, 6 inches diameter.
1st wheel B, 36 ,, ,,
2nd pinion C, 10 ,, ,,
2nd wheel D, 60 ,, ,,
3rd pinion E, 20 ,, ,,
3rd wheel F, 80 ,, ,,

Diameter of the barrel at the centre of the chain = 20 inches. Radius of the handles = 16 inches,

then $\dfrac{60 \text{ lbs. strain at the handles} \times 16 \text{ radius of the handle}}{3 \text{ inches radius of first pinion A}} = 320$ lbs. strain at the pitch lines of wheels A and B.

$\dfrac{320 \text{ lbs.} \times 18 \text{ inches radius of first wheel B}}{5 \text{ inches radius ot second pinion C}} = 1152$ lbs. strain at the pitch lines of wheels C and D.

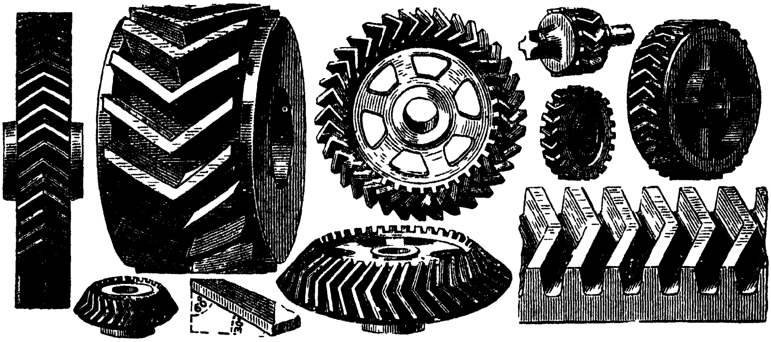
$\dfrac{1152 \text{ lbs.} \times 30 \text{ inches radius of second wheel D}}{10 \text{ inches radius of third pinion E}} = 3456$ lbs. strain at the pitch lines of wheels E and F.

$\dfrac{3456 \text{ lbs.} \times 40 \text{ radius of third wheel F}}{10 \text{ inches radius of barrel at the centre of the chain}} = 13824$ lbs. strain on the chain,

or $\dfrac{13824}{2240} = 6{\cdot}126$ tons, and as the snatch block, or running pulley, will double the power, about $12\frac{1}{4}$ tons would be lifted by the 4 men.

Double Helical Toothed-Wheels, shown in the engraving on the next page, possess a strong and durable form of tooth; they work smoothly and almost noiselessly, without vibration, and the teeth always keep in the right plane of revolution. As angular teeth of this form approach to, and recede from each other more gradually than ordinary straight teeth, a more perfect rolling motion is obtained. A good angle for the teeth is 30°, from the straight line or 60° from the side of the wheel, but the angle may be varied.

The Strength of Double Helical Toothed-Wheels with teeth at an angle of 30°, is 20 per cent. greater than the strength of ordinary toothed-wheels of the same pitch and width.



Figs. 101–110.—Double Helical Toothed Wheels.

The Horse-power of Double Helical Toothed-Wheels, having teeth at the above angle, may be found by this Rule. Multiply together the square of the pitch in inches, the width of face in inches, the diameter of the wheel at the pitch circle in feet, the number of revolutions per minute, and divide the product by the constant number 200, the quotient will be the actual or indicated horse-power which that wheel will properly transmit.

Frictional Gearing.—The pitch of frictional gearing varies from $\frac{1}{4}$ inch to 1 inch; the driving power is one sixth of the interpressure between the wheels. Fig. 111 is a full size section of teeth 1 inch pitch—which is the pitch generally used for hoists—and represents the exact form of tooth found to answer best in practice for this purpose. Thickness of tooth = $\frac{3}{5}$ths the pitch : width of space between the teeth = $\frac{2}{5}$ths the pitch : depth of tooth = $\frac{4}{5}$ths the pitch : angle of point of tooth = 70°.

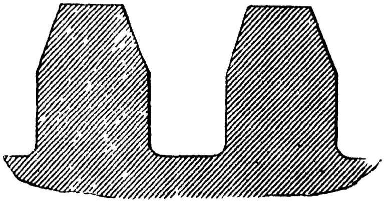


Fig. 111.—Frictional Gearing.

Rope - Gearing. — Rope driving-gear is used for transmitting power from the fly-wheel of engines, &c.; it is best adapted for driving shafts which run at high and uniform speeds, such as the main- shafts of factories. For such purposes its cost is about one-third that of belt-gearing. The ropes are generally made of hemp of $4\frac{3}{4}$ inches circumference for small powers, and $5\frac{1}{4}$ and $6\frac{1}{2}$ inches circum-

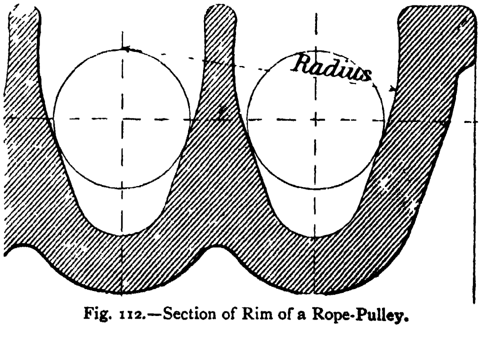


Fig. 112.—Section of Rim of a Rope-Pulley.

ference for large powers. The slack or return side of the rope should be at the top, and the tight or driving side at the bottom of the pulleys. The ropes are never tightened to run straight over the tops of the pulleys, but hang with a good sag between the pulleys. Fig. 112 shows the form of pulley used for rope gearing. The sides of the grooves below the centre of the rope are inclined at an angle of 45°; the distance between the centres of the grooves is equal to from ·45 to one-half the circumference of the rope; the distance of the centre of the rope from the top of the pulley, and also from the bottom of the groove is $\frac{7}{8}$ths of the diameter of the rope. The circumference of the smallest pulley should not be less than thirty times the diameter of the rope. The circumferential velocity of the fly-wheel may be from 3000 to 5000 feet per minute—but a speed of 4500 feet gives, probably, the best results in practice. The shafts should be from 30 feet to 80 feet apart The splice of the rope should be about 10 feet long. Soft soap is the best lubricant for the ropes.

Weight of Pulleys for Rope-Gearing.—The weight of cast-iron rope pulleys—turned and finished—made to the above proportions, may be calculated approximately by the following rule: Multiply the square of the pitch of the grooves in inches by the number of grooves, and by the diameter of the pulley in feet, and divide the last product by one of the following constant numbers, viz., by 13 if the pulley is cast whole; or by 10 if it is split—that is, in halves and bolted together;—and the quotient will be the weight in cwts.

Weight of Cast-Iron Rope-Pulleys—Turned and Finished—for Ropes 2 Inches Diameter.—Pitch of grooves, $2\frac{7}{8}$ inches; the sizes above 8 feet diameter being in halves and bolted together.

Diameter, in feet . . .	5	6	7	8	9	10	11	12	13	14	15
Bore of pulley, in inches .	5	6	$6\frac{1}{2}$	7	8	$8\frac{1}{2}$	9	10	11	12	13
Number of ropes. . .	5	7	8	8	9	9	10	10	10	12	14
Weight, in cwts. . .	15	26	35	40	66	74	90	99	107	139	173

Horse-power of Rope-Gearing.—To find the number of indicated horse-power transmitted by rope-gearing. *Rule:* Multiply 8 times the square of the circumference of one rope by the number of ropes, and by the circumferential velocity of the driving pulley in feet per minute; and divide the product by 33,000.

Strength of Ropes for Rope-Gearing.—The breaking strength of the untarred or white hemp-ropes used for rope-belts, varies from 6,400 lbs. to 11,000 lbs. per square inch; the average breaking strength being 8,700 lbs. per square inch. The working strength is one-sixth of the breaking strength or 1,450 lbs. per square inch.

Weight of Rope-Belts.—Rope-belts, 1¾ inches diameter, weigh about 3 lbs. per yard, and rope-belts, 2 inches diameter, weigh about 4 lbs. per yard, the weight of the rope in lbs. per yard being approximately equal to the square of the diameter of the rope in inches.

Friction of Rope-Belts.—The friction of a rope working in a taper groove on a cast-iron pulley is three times greater than that of a rope working on a cast-iron pulley without a groove. The co-efficient of friction for a rope on a cast-iron pulley without a groove being ·28; that of a rope working in a taper groove on a cast-iron pulley is ·28 × 3 = ·84, when the groove is not greased. If the groove be greased the co-efficient of friction is reduced to the extent of one-half. Rope-gearing absorbs more power than toothed-wheel gearing The percentage of the total power developed by the engine expended in overcoming the friction of the engine, shafting and machinery in factories, averages at least 25 per cent, when driven by toothed-wheel gearing, and 32 per cent by rope-gearing.

The weight of cast-iron toothed-wheel gearing may be found approximately by the following rule. Multiply the number of teeth by the square of the pitch in inches, and by the width of the face in inches; and divide the product by one of the following constant numbers, which will give the weight of the wheel in lbs.

2·2 for spur mortice wheels complete with wood teeth.
2·4 for iron toothed spur wheels.
2·6 for bevel and mitre wheels complete with wood teeth.
2·9 for bevel and mitre iron toothed wheels.

The weight of cast-iron spur wheels, cast from a good set of patterns, is given in table 19; the weight of cast iron bevel and mitre wheels, is one-sixth less than the weight of cast iron spur wheels. The weight of spur and bevel mortice wheels complete with wood teeth, is one-tenth more than similar wheels of cast iron.

The horse-power of an ordinary spur wheel may be found by multiplying the horse-power given in Table 19 by the number of revolutions the wheel will make per minute.

The weight of small spur wheels, commonly called change wheels, is given at page 319.

Machine-Moulded Wheels vary much in weight, and are usually made unnecessarily heavy,—wheels being sold by weight, many ironfounders make them as heavy as they can—their weight being generally from 25 to 50 per cent. heavier than pattern-moulded wheels. The weight of machine-moulded toothed-wheels may be found approximately by adding 30 per cent. to the weight of the pattern-moulded wheels given in Table 19, this percentage being the average overweight of a large number of machine-moulded wheels.

The Weight of Cast-Steel Wheel-Castings may be found by adding 1 lb. for every 12 lbs. weight of similar wheels of cast-iron. The Breaking strain per square inch of section of good ordinary mild-steel castings varies from 28 to 34 tons, with from 10 to 15 per cent. elongation.

TABLE 19.—WEIGHT AND HORSEPOWER OF CAST-IRON SPUR-WHEELS.

Number of Teeth.	Pitch 1⅛ In. Face, 3 In. Wide.						Pitch 1¼ In. Face, 3½ In. Wide.						Pitch 1⅜ In. Face, 3⅜ In. Wide.					
	Diameter of Pitch Circle.		Weight of Spur Wheel Casting.			Horse Power at one Revolution per Minute.	Diameter of Pitch Circle.		Weight of Spur Wheel Casting.			Horse Power at one Revolution per Minute.	Diameter of Pitch Circle.		Weight of Spur Wheel Casting.			Horse Power at one Revolution per Minute.
	ft.	in.	cwt.	qr.	lb.		ft.	in.	cwt.	qr.	lb.		ft.	in.	cwt.	qr.	lb.	
13	0	4¾	0	0	18	·0050	0	5¼	0	0	26	·0090	0	5¾	0	1	6	·013
14	0	5	0	0	19	·0055	0	5⅝	0	0	27	·0100	0	6¼	0	1	9	·014
15	0	5⅜	0	0	20	·0060	0	6	0	1	1	·0110	0	6⅝	0	1	11	·015
16	0	5¾	0	0	21	·0070	0	6⅜	0	1	3	·0116	0	7	0	1	13	·016
17	0	6⅛	0	0	22	·0076	0	6¾	0	1	5	·0123	0	7½	0	1	15	·018
18	0	6½	0	0	23	·0081	0	7⅛	0	1	7	·0129	0	8	0	1	17	·019
19	0	6⅞	0	0	24	·0085	0	7½	0	1	9	·0136	0	8⅜	0	1	19	·020
20	0	7⅛	0	0	25	·0088	0	8	0	1	11	·0145	0	8⅞	0	1	21	·021
21	0	7½	0	0	27	·0093	0	8⅜	0	1	13	·0151	0	9¼	0	1	24	·022
22	0	7⅞	0	1	0	·0097	0	8¾	0	1	15	·0159	0	9⅝	0	1	27	·023
23	0	8¼	0	1	1	·0102	0	9⅛	0	1	17	·0167	0	10	0	2	3	·024
24	0	8⅝	0	1	2	·0107	0	9½	0	1	19	·0173	0	10½	0	2	6	·025
25	0	9	0	1	3	·0112	0	10	0	1	21	·0182	0	11	0	2	8	·026
26	0	9¼	0	1	4	·0116	0	10⅜	0	1	23	·0189	0	11½	0	2	10	·027
27	0	9⅝	0	1	5	·0120	0	10¾	0	1	25	·0195	0	11⅞	0	2	12	·028
28	0	10	0	1	8	·0125	0	11¼	0	1	27	·0204	1	0¼	0	2	14	·029
29	0	10⅜	0	1	10	·0129	0	11⅝	0	2	2	·0211	1	0¾	0	2	16	·030
30	0	10¾	0	1	12	·0134	1	0	0	2	4	·0227	1	1⅛	0	2	18	·031
31	0	11⅛	0	1	13	·0138	1	0⅜	0	2	6	·0233	1	1⅝	0	2	21	·032
32	0	11½	0	1	14	·0143	1	0¾	0	2	8	·0240	1	2	0	2	24	·033
33	0	11⅞	0	1	15	·0147	1	1⅛	0	2	10	·0247	1	2½	0	3	0	·034
34	1	0⅛	0	1	17	·0152	1	1⅝	0	2	12	·0248	1	3	0	3	4	·035
35	1	0⅝	0	1	18	·0157	1	2	0	2	15	·0255	1	3⅜	0	3	8	·036
36	1	1	0	1	19	·0161	1	2⅜	0	2	18	·0261	1	3¾	0	3	12	·037
37	1	1¼	0	1	20	·0165	1	2¾	0	2	20	·0268	1	4¼	0	3	16	·038
38	1	1⅝	0	1	22	·0170	1	3¼	0	2	23	0279	1	4⅝	0	3	20	·039
39	1	2	0	1	23	·0174	1	3½	0	2	25	·0283	1	5	0	3	22	·040
40	1	2⅜	0	1	24	·0179	1	4	0	2	27	·0292	1	5½	0	3	25	·041
41	1	2¾	0	1	25	·0183	1	4⅜	0	3	2	·0299	1	6	1	0	1	·042
42	1	3	0	1	27	·0188	1	4¾	0	3	6	·0305	1	6⅜	1	0	4	·043
43	1	3½	0	2	0	·0193	1	5⅛	0	3	9	·0312	1	6⅞	1	0	7	·044
44	1	3¾	0	2	3	·0197	1	5⅝	0	3	11	·0321	1	7¼	1	0	10	·045
45	1	4⅛	0	2	6	·0201	1	6	0	3	13	·0330	1	7¾	1	0	13	·046
46	1	4½	0	2	8	·0205	1	6⅜	0	3	16	·0336	1	8⅛	1	0	16	·047
47	1	4⅞	0	2	10	·0210	1	6¾	0	3	19	·0343	1	8⅝	1	0	19	·048
48	1	5¼	0	2	13	·0215	1	7⅛	0	3	21	·0349	1	9	1	0	22	·049
49	1	5⅝	0	2	15	·0220	1	7½	0	3	23	·0356	1	9½	1	0	25	·050
50	1	6	0	2	17	·0225	1	8	0	3	25	·0365	1	9⅞	1	1	0	·051
51	1	6¼	0	2	18	·0228	1	8⅜	1	0	0	·0371	1	10⅜	1	1	2	·052
52	1	6⅝	0	2	19	·0232	1	8¾	1	0	3	·0378	1	10¾	1	1	5	·053
53	1	6⅞	0	2	20	·0235	1	9⅛	1	0	6	·0387	1	11¼	1	1	8	·054
54	1	7⅜	0	2	21	·0240	1	9½	1	0	8	·0393	1	11⅝	1	1	11	·055
55	1	7¾	0	2	22	·0245	1	9⅞	1	0	10	·0400	2	0	1	1	15	·056
56	1	8⅛	0	2	24	·0250	1	10¼	1	0	13	·0407	2	0½	1	1	18	·057

TABLE 19 *con.*—WEIGHT AND HORSEPOWER OF CAST-IRON SPUR-WHEELS.

Number of Teeth.	PITCH 1⅛ IN. FACE, 3 IN. WIDE.						PITCH 1¼ IN. FACE, 3½ IN. WIDE.						PITCH 1⅜ IN FACE, 3¾ IN. WIDE.					
	Diameter of Pitch Circle.		Weight of Spur Wheel Casting.			Horse Power at one Revolution per Minute.	Diameter of Pitch Circle.		Weight of Spur Wheel Casting.			Horse Power at one Revolution per Minute.	Diameter of Pitch Circle.		Weight of Spur Wheel Casting.			Horse Power at one Revolution per Minute.
	ft.	in.	cwt.	qr.	lb.		ft.	in.	cwt.	qr.	lb.		ft.	in.	cwt.	qr.	lb.	
57	1	8½	0	2	26	·0255	1	10⅝	1	0	15	·0413	2	0⅞	1	1	21	·059
58	1	8¾	0	3	0	·0260	1	11	1	0	18	·0420	2	1⅜	1	1	24	·060
59	1	9⅛	0	3	2	·0264	1	11½	1	0	20	·0429	2	1⅞	1	1	27	·061
60	1	9⅜	0	3	4	·0268	1	11⅞	1	0	23	·0435	2	2¼	1	2	2	·062
61	1	9⅞	0	3	5	·0272	2	0¼	1	0	25	·0460	2	2¾	1	2	6	·063
62	1	10¼	0	3	7	·0276	2	0⅝	1	1	0	·0466	2	3⅛	1	2	9	·064
63	1	10½	0	3	9	·0280	2	1	1	1	3	·0474	2	3½	1	2	12	·065
64	1	10⅞	0	3	11	·0285	2	1½	1	1	5	·0480	2	4	1	2	15	·066
65	1	11¼	0	3	13	·0290	2	1⅞	1	1	8	·0485	2	4½	1	2	17	·067
66	1	11⅝	0	3	15	·0294	2	2¼	1	1	10	·0490	2	4⅞	1	2	20	·068
67	2	0	0	3	17	·0300	2	2⅝	1	1	12	·0495	2	5¼	1	2	23	·069
68	2	0⅜	0	3	19	·0304	2	3	1	1	15	·0497	2	5¾	1	2	26	·070
69	2	0¾	0	3	20	·0308	2	3½	1	1	17	·0503	2	6¼	1	3	0	·071
70	2	1	0	3	21	·0310	2	3⅞	1	1	20	·0511	2	6⅝	1	3	3	·072
71	2	1½	0	3	22	·0316	2	4¼	1	1	22	·0517	2	7	1	3	6	·073
72	2	1¾	0	3	24	·0320	2	4⅝	1	1	25	·0522	2	7½	1	3	9	·074
73	2	2⅛	0	3	25	·0325	2	5	1	2	0	·0530	2	8	1	3	12	·075
74	2	2½	0	3	26	·0330	2	5½	1	2	3	·0536	2	8⅜	1	3	15	·076
75	2	2⅞	0	3	27	·0335	2	5⅞	1	2	5	·0545	2	8⅞	1	3	18	·077
76	2	3¼	1	0	0	·0340	2	6¼	1	2	8	·0558	2	9¼	1	3	21	·078
77	2	3½	1	0	2	·0344	2	6⅝	1	2	11	·0561	2	9¾	1	3	24	·079
78	2	3⅞	1	0	4	·0348	2	7	1	2	13	·0566	2	10⅛	1	3	27	·080
79	2	4⅛	1	0	6	·0353	2	7⅜	1	2	16	·0580	2	10½	2	0	3	·081
80	2	4⅝	1	0	8	·0358	2	7¾	1	2	18	·0584	2	11	2	0	6	·082
81	2	5	1	0	10	·0363	2	8¼	1	2	21	·0589	2	11½	2	0	11	·083
82	2	5⅜	1	0	12	·0366	2	8⅝	1	2	23	·0598	2	11⅞	2	0	14	·084
83	2	5¾	1	0	14	·0370	2	9	1	2	25	·0605	3	0⅜	2	0	17	·085
84	2	6	1	0	16	·0375	2	9⅜	1	2	27	·0610	3	0¾	2	0	20	·086
85	2	6⅜	1	0	18	·0380	2	9¾	1	3	2	·0618	3	1¼	2	0	23	·087
86	2	6¾	1	0	20	·0386	2	10¼	1	3	4	·0624	3	1⅝	2	0	24	·088
87	2	7⅛	1	0	22	·0390	2	10⅝	1	3	7	·0633	3	2	2	0	27	·089
88	2	7½	1	0	24	·0394	2	11	1	3	10	·0642	3	2½	2	1	3	·090
89	2	7⅞	1	0	26	·0398	2	11⅜	1	3	12	·0646	3	2⅞	2	1	7	·091
90	2	8¼	1	1	0	·0402	2	11¾	1	3	15	·0660	3	3¼	2	1	10	·092
91	2	8½	1	1	2	·0404	3	0¼	1	3	18	·0664	3	3⅞	2	1	13	·093
92	2	8⅞	1	1	4	·0410	3	0⅝	1	3	20	·0672	3	4¼	2	1	15	·094
93	2	9¼	1	1	6	·0415	3	1	1	3	22	·0680	3	4¾	2	1	18	·095
94	2	9⅝	1	1	8	·0420	3	1⅜	1	3	25	·0686	3	5⅛	2	1	21	·096
95	2	10	1	1	10	·0425	3	1¾	2	0	0	·0690	3	5½	2	1	24	·097
96	2	10⅜	1	1	12	·0430	3	2⅛	2	0	3	·0698	3	6	2	2	0	·098
97	2	10¾	1	1	14	·0435	3	2⅝	2	0	6	·0706	3	6½	2	2	4	·099
98	2	11	1	1	16	·0440	3	3	2	0	9	·0712	3	6⅞	2	2	8	·100
99	2	11⅜	1	1	18	·0445	3	3⅜	2	0	12	·0721	3	7⅜	2	2	11	·101
100	2	11⅞	1	1	20	·0450	3	3¾	2	0	14	·0730	3	7¾	2	2	14	·102

TABLE 19 *con.*—WEIGHT AND HORSEPOWER OF CAST-IRON SPUR-WHEELS

Number of Teeth.	Pitch 1½ In., Face 4 In. Wide.						Pitch 1⅝ In., Face 4½ In. Wide						Pitch 1¾ In., Face 5 In. Wide.					
	Diameter of Pitch Circle.		Weight of Spur Wheel Casting.			Horse Power at one Revolution per Minute	Diameter of Pitch Circle.		Weight of Spur Wheel Casting.			Horse Power at one Revolution per Minute.	Diameter of Pitch Circle.		Weight of Spur Wheel Casting.			Horse Power at one Revolution per Minute.
	ft.	in.	cwt.	qr	lb.		ft.	in.	cwt.	qr.	lb.		ft.	in.	cwt.	qr.	lb.	
13	0	6¼	0	1	14	·019	0	6¾	0	1	26	·026	0	7¼	0	2	15	·037
14	0	6¾	0	1	17	·020	0	7¼	0	2	3	·028	0	7¾	0	2	22	·039
15	0	7⅛	0	1	19	·021	0	7¾	0	2	7	·030	0	8⅜	0	3	0	·042
16	0	7⅝	0	1	23	·023	0	8¼	0	2	11	·032	0	9	0	3	4	·046
17	0	8⅛	0	1	26	·024	0	8⅞	0	2	15	·035	0	9½	0	3	8	·048
18	0	8⅝	0	2	0	·026	0	9⅜	0	2	20	·037	0	10	0	3	13	·051
19	0	9⅛	0	2	4	·028	0	9⅞	0	2	24	·039	0	10⅝	0	3	16	·054
20	0	9⅝	0	2	8	·029	0	10⅜	0	3	0	·041	0	11¼	0	3	22	·057
21	0	10	0	2	11	·030	0	11	0	3	4	·043	0	11¾	1	0	0	·060
22	0	10½	0	2	14	·031	0	11½	0	3	8	·045	1	0⅜	1	0	7	·063
23	0	11	0	2	16	·033	1	0	0	3	12	·048	1	0⅞	1	0	14	·066
24	0	11½	0	2	18	·035	1	0½	0	3	16	·049	1	1½	1	0	21	·069
25	1	0	0	2	25	·037	1	1	0	3	22	·051	1	2	1	1	0	·072
26	1	0½	0	3	0	·038	1	1½	0	3	27	·053	1	2½	1	1	7	·074
27	1	1	0	3	3	·040	1	2	1	0	5	·055	1	3	1	1	14	·077
28	1	1⅜	0	3	6	·041	1	2½	1	0	12	·056	1	3⅝	1	1	21	·080
29	1	1⅞	0	3	9	·042	1	3	1	0	17	·058	1	4⅛	1	2	0	·082
30	1	2⅜	0	3	12	·043	1	3½	1	0	23	·060	1	4⅝	1	2	7	·085
31	1	2¾	0	3	15	·044	1	4	1	1	0	·063	1	5¼	1	2	14	·088
32	1	3¼	0	3	20	·046	1	4⅝	1	1	6	·065	1	5⅞	1	2	21	·091
33	1	3¾	0	3	25	·047	1	5⅛	1	1	12	·068	1	6½	1	3	0	·095
34	1	4¼	1	0	2	·048	1	5⅝	1	1	19	·070	1	7	1	3	7	·098
35	1	4¾	1	0	7	·050	1	6⅛	1	1	25	·072	1	7½	1	3	14	·100
36	1	5¼	1	0	12	·052	1	6⅝	1	2	4	·074	1	8	1	3	21	·102
37	1	5⅝	1	0	16	·053	1	7⅛	1	2	9	·076	1	8⅝	2	0	0	·106
38	1	6⅛	1	0	20	·056	1	7⅝	1	2	14	·078	1	9¼	2	0	7	·109
39	1	6⅝	1	0	24	·057	1	8⅛	1	2	20	·080	1	9¾	2	0	14	·112
40	1	7	1	1	0	·058	1	8¾	1	2	25	·082	1	10⅜	2	0	21	·115
41	1	7⅝	1	1	4	·059	1	9¼	1	3	2	·084	1	10⅞	2	1	0	·118
42	1	8	1	1	8	·060	1	9¾	1	3	8	·086	1	11½	2	1	7	·121
43	1	8⅝	1	1	12	·062	1	10¼	1	3	14	·088	2	0	2	1	14	·124
44	1	9	1	1	16	·063	1	10¾	1	3	20	·090	2	0½	2	1	21	·126
45	1	9½	1	1	20	·065	1	11⅜	1	3	22	·093	2	1	2	2	0	·129
46	1	10	1	1	24	·066	1	11⅞	2	0	0	·096	2	1⅝	2	2	7	·132
47	1	10½	1	2	0	·068	2	0⅜	2	0	5	·097	2	2⅛	2	2	14	·135
48	1	11	1	2	4	·070	2	0⅞	2	0	10	·099	2	2¾	2	2	21	·137
49	1	11½	1	2	8	·072	2	1⅜	2	0	16	·101	2	3⅜	2	3	0	·140
50	2	0	1	2	12	·074	2	1⅞	2	0	22	·102	2	3⅞	2	3	7	·143
51	2	0⅜	1	2	16	·075	2	2⅜	2	1	0	·105	2	4½	2	3	14	·146
52	2	0⅞	1	2	20	·076	2	2⅞	2	1	5	·107	2	4⅞	2	3	21	·148
53	2	1¼	1	2	24	·078	2	3⅜	2	1	10	·110	2	5½	3	0	0	·152
54	2	1¾	1	3	0	·080	2	3⅞	2	1	15	·111	2	6	3	0	7	·155
55	2	2¼	1	3	4	·081	2	4½	2	1	21	·113	2	6⅝	3	0	14	·158
56	2	2¾	1	3	8	·083	2	4⅞	2	1	26	·115	2	7⅛	3	0	21	·160

Table 19 *con.*—Weight and Horsepower of Cast-Iron Spur-Wheels

Number of Teeth.	Pitch 1½ In., Face 4 In. Wide.						Pitch 1⅝ In., Face 4½ In. Wide.						Pitch 1¾ In., Face 5 In. Wide.					
	Diameter of Pitch Circle.		Weight of Spur Wheel Casting.			Horse Power at one Revolution per Minute.	Diameter of Pitch Circle.		Weight of Spur Wheel Casting.			Horse Power at one Revolution per Minute.	Diameter of Pitch Circle.		Weight of Spur Wheel Casting.			Horse Power at one Revolution per Minute.
	ft.	in.	cwt.	qr.	lb.		ft.	in.	cwt.	qr.	lb.		ft.	in.	cwt.	qr.	lb.	
57	2	3¼	1	3	12	·084	2	5¼	2	2	3	·116	2	7¾	3	1	0	·163
58	2	3⅝	1	3	16	·085	2	6	2	2	8	·120	2	8¼	3	1	7	·166
59	2	4⅛	1	3	20	·086	2	6½	2	2	14	·121	2	8⅞	3	1	14	·169
60	2	4⅝	1	3	24	·087	2	7	2	2	19	·123	2	9⅜	3	1	21	·172
61	2	5¼	2	0	0	·088	2	7½	2	2	25	·125	2	10	3	2	0	·175
62	2	5⅝	2	0	4	·089	2	8	2	3	4	·127	2	10½	3	2	7	·178
63	2	6	2	0	8	·091	2	8⅝	2	3	10	·130	2	11	3	2	14	·180
64	2	6½	2	0	12	·092	2	9⅛	2	3	17	·132	2	11⅝	3	2	21	·183
65	2	7	2	0	16	·094	2	9⅝	2	3	23	·134	3	0¼	3	3	0	·187
66	2	7½	2	0	20	·095	2	10⅛	3	0	3	·136	3	0¾	3	3	10	·190
67	2	8	2	0	24	·096	2	10⅝	3	0	10	·138	3	1⅜	3	3	18	·193
68	2	8½	2	1	0	·097	2	11⅛	3	0	16	·140	3	1⅞	3	3	24	·195
69	2	8⅞	2	1	4	·100	2	11¾	3	0	21	·142	3	2⅜	4	0	4	·198
70	2	9⅜	2	1	8	·102	3	0¼	3	1	0	·144	3	3	4	0	10	·201
71	2	9⅞	2	1	12	·103	3	0¾	3	1	6	·146	3	3½	4	0	17	·204
72	2	10⅜	2	1	16	·104	3	1¼	3	1	13	·148	3	4⅛	4	0	22	·207
73	2	10⅞	2	1	20	·105	3	1¾	3	1	19	·150	3	4⅝	4	1	0	·210
74	2	11⅜	2	1	24	·106	3	2¼	3	1	24	·152	3	5¼	4	1	6	·212
75	2	11⅞	2	2	0	·109	3	2¾	3	2	0	·154	3	5¾	4	1	11	·215
76	3	0¼	2	2	4	·111	3	3¼	3	2	5	·156	3	6⅜	4	1	16	·218
77	3	0¾	2	2	8	·112	3	3⅞	3	2	10	·158	3	6⅞	4	1	20	·221
78	3	1¼	2	2	12	·113	3	4⅜	3	2	15	·160	3	7½	4	1	24	·224
79	3	1¾	2	2	16	·114	3	4⅞	3	2	20	·162	3	8	4	2	0	·227
80	3	2¼	2	2	20	·116	3	5⅜	3	2	26	·165	3	8½	4	2	6	·230
81	3	2⅝	2	2	24	·118	3	5⅞	3	3	6	·168	3	9⅛	4	2	11	·233
82	3	3⅛	2	3	0	·120	3	6⅜	3	3	13	·170	3	9⅝	4	2	16	·236
83	3	3⅝	2	3	4	·121	3	6⅞	3	3	20	·172	3	10¼	4	2	20	·238
84	3	4	2	3	8	·123	3	7½	4	0	0	·174	3	10¾	4	2	24	·240
85	3	4½	2	3	12	·124	3	7⅞	4	0	7	·176	3	11¼	4	3	4	·243
86	3	5	2	3	16	·125	3	8½	4	0	14	·178	3	11⅞	4	3	8	·246
87	3	5½	2	3	20	·126	3	9	4	0	20	·180	4	0½	4	3	13	·250
88	3	6	2	3	24	·128	3	9½	4	0	26	·182	4	1	4	3	18	·252
89	3	6½	3	0	0	·129	3	10	4	1	3	·184	4	1½	4	3	24	·255
90	3	7	3	0	4	·131	3	10½	4	1	8	·186	4	2⅛	5	0	2	·258
91	3	7½	3	0	8	·133	3	11	4	1	13	·188	4	2¾	5	1	7	·261
92	3	7⅞	3	0	12	·134	3	11⅝	4	1	18	·190	4	3¼	5	1	14	·264
93	3	8⅜	3	0	16	·135	4	0⅛	4	1	23	·192	4	3⅞	5	1	21	·267
94	3	8⅞	3	0	20	·137	4	0⅝	4	1	26	·194	4	4⅜	5	2	0	·269
95	3	9⅜	3	0	24	·138	4	1⅛	4	2	3	·196	4	4⅞	5	2	7	·272
96	3	9¾	3	1	0	·140	4	1⅝	4	2	8	·198	4	5½	5	2	14	·275
97	3	10¼	3	1	4	·142	4	2⅛	4	2	13	·200	4	6	5	2	21	·279
98	3	10¾	3	1	8	·144	4	2⅝	4	2	18	·202	4	6½	5	3	0	·281
99	3	11¼	3	1	12	·146	4	3¼	4	2	23	·204	4	7⅛	5	3	7	·284
100	3	11¾	3	1	16	·148	4	3¾	4	3	0	·206	4	7¾	5	3	14	·287

TABLE 19 *con.*—WEIGHT AND HORSEPOWER OF CAST-IRON SPUR-WHEELS.

Number of Teeth.	Pitch 1⅞ In., Face 5½ In. Wide						Pitch 2 In., Face 6 In. Wide						Pitch 2¼ In., Face 7 In. Wide.					
	Diameter of Pitch Circle.		Weight of Spur Wheel Casting			Horse Power at one Revolution per Minute.	Diameter of Pitch Circle.		Weight of Spur Wheel Casting			Horse Power at one Revolution per Minute	Diameter of Pitch Circle		Weight of Spur Wheel Casting.			Horse Power at one Revolution per Minute.
	ft.	in.	cwt.	qr.	lb		ft.	in	cwt.	qr.	lb		ft.	in	cwt.	qr.	lb.	
13	0	7⅞	0	3	13	·052	0	8⅜	1	0	0	·069	0	9⅜	1	2	0	082
14	0	8½	0	3	16	·056	0	9	1	0	7	·075	0	10	1	2	14	·087
15	0	9	0	3	20	·060	0	9⅝	1	0	14	·080	0	10¾	1	2	24	·094
16	0	9⅝	0	3	24	·064	0	10¼	1	0	21	·085	0	11½	1	3	8	·100
17	0	10¼	1	0	0	·070	0	10⅞	1	1	3	·090	1	0¼	1	3	18	·108
18	0	10¾	1	0	5	·073	0	11½	1	1	13	·095	1	0⅞	2	0	6	·113
19	0	11⅜	1	0	10	·075	1	0⅛	1	1	24	·101	1	1⅝	2	0	22	·117
20	1	0	1	0	15	·080	1	0¾	1	2	8	·106	1	2⅜	2	1	10	·126
21	1	0½	1	0	20	·083	1	1½	1	2	20	·112	1	3	2	2	0	·132
22	1	1⅛	1	0	26	·087	1	2	1	3	4	·116	1	3¾	2	2	16	·138
23	1	1¾	1	1	5	·092	1	2⅝	1	3	16	·121	1	4½	2	3	6	·145
24	1	2⅜	1	1	13	095	1	3⅜	2	0	0	·128	1	5¼	2	3	20	·154
25	1	2⅞	1	1	20	·098	1	3⅞	2	0	12	·132	1	6	3	0	10	·159
26	1	3½	1	2	0	·103	1	4½	2	0	24	·137	1	6⅝	3	1	0	·160
27	1	4⅛	1	2	8	·107	1	5¼	2	1	8	·143	1	7⅜	3	1	16	·164
28	1	4¾	1	2	16	·110	1	5¾	2	1	18	·147	1	8	3	2	0	·175
29	1	5⅜	1	2	24	·115	1	6½	2	2	0	·154	1	8¾	3	2	15	·182
30	1	6	1	3	4	·119	1	7⅛	2	2	10	·159	1	9½	3	3	0	·189
31	1	6½	1	3	12	·123	1	7¾	2	2	20	·164	1	10¼	3	3	14	·196
32	1	7⅛	1	3	20	·127	1	8⅜	2	3	0	·169	1	11	4	0	0	·201
33	1	7¾	2	0	0	·131	1	9	2	3	10	·175	1	11⅝	4	0	14	·207
34	1	8⅜	2	0	8	·136	1	9⅝	2	3	20	·180	2	0⅜	4	1	3	·214
35	1	9	2	0	16	·140	1	10⅛	3	0	0	·184	2	1	4	1	20	·220
36	1	9½	2	0	24	·143	1	10⅞	3	0	10	·190	2	2	4	2	6	·227
37	1	10	2	1	4	·148	1	11½	3	0	20	·195	2	2½	4	2	20	·233
38	1	10¾	2	1	12	·152	2	0¼	3	1	3	·202	2	3¼	4	3	6	·240
39	1	11⅜	2	1	20	·155	2	0⅞	3	1	13	·207	2	4	4	3	20	·246
40	1	11⅞	2	2	0	·158	2	1½	3	1	23	·212	2	4⅝	5	0	5	·252
41	2	0½	2	2	8	·162	2	2⅛	3	2	5	·217	2	5⅜	5	0	21	·258
42	2	1	2	2	16	166	2	2¾	3	2	14	·221	2	6	5	1	9	·265
43	2	1⅝	2	2	24	·170	2	3⅜	3	2	24	·228	2	6¾	5	1	24	·271
44	2	2¼	2	3	4	·174	2	4	3	3	8	·233	2	7½	5	2	10	·278
45	2	2⅞	2	3	13	·179	2	4⅝	3	3	18	·238	2	8¼	5	2	24	·284
46	2	3½	2	3	22	·183	2	5¼	4	0	0	243	2	9	5	3	10	·290
47	2	4	3	0	3	·187	2	6	4	0	10	·250	2	9⅝	5	3	24	·296
48	2	4⅝	3	0	12	·190	2	6½	4	0	20	·254	2	10⅜	6	0	10	·308
49	2	5¼	3	0	22	·194	2	7¼	4	1	0	·260	2	11	6	0	26	·311
50	2	5⅞	3	1	5	·198	2	7⅞	4	1	10	·265	2	11¾	6	1	14	·316
51	2	6½	3	1	14	·203	2	8½	4	1	21	·270	3	0½	6	2	1	·322
52	2	7⅛	3	1	24	·207	2	9⅛	4	2	4	·276	3	1¼	6	2	15	·328
53	2	7⅝	3	2	6	·210	2	9¾	4	2	14	·281	3	2	6	3	2	·334
54	2	8¼	3	2	15	·212	2	10⅜	4	2	24	·286	3	2⅝	6	3	16	·341
55	2	8⅞	3	2	24	·217	2	11	4	3	7	·291	3	3½	7	0	4	·348
56	2	9⅜	3	3	8	·222	2	11⅝	4	3	18	·296	3	4⅛	7	0	18	·354

SIZING AND CUTTING GEAR WHEELS.

Diameter, when applied to gears, is always understood to mean pitch diameter.

Diametral Pitch is the number of teeth to each inch of pitch diameter. *Example :* If a gear has 40 teeth and the pitch diameter is 4 in., there are 10 teeth to each inch of the pitch diameter and the diametral pitch is 10, or in other words, the gear is 10 diametral pitch.

Diametral Pitch required, circular pitch given. Divide 3·1416 by the circular pitch. *Example :* If the circular pitch is 2 in., divide 3·1415 by 2, and the quotient, 1·5708, is the diametral pitch.

Diametral Pitch required, number of teeth and outside diameter given. Add 2 to the number of teeth and divide by the outside diameter.

Example : If the number of teeth is 40, the diameter of the blank is 10½ in. ; add 2 to the number of teeth, making 42, and divide by 10½ ; the quotient, 4, is the diametral pitch.

Circular Pitch is the distance from the centre of one tooth to the centre of the next, measured along the pitch pine. *Example :* If the distance from the centre of one tooth to the centre of next tooth, measured along the pitch circle, is ½ in., the gear is ½ in. circular pitch.

Circular Pitch required, diametral pitch given. Divide 3·1416 by diametral pitch. *Example :* If the diametral pitch is 4, divide 3·1416 by 4, and the quotient, ·7854 in., is the circular pitch.

Number of Teeth required, pitch diameter and diametral pitch given. Multiply pitch diameter by diametral pitch. *Example :* If the diameter of the pitch circle is 10 in. and the diametral pitch is 4, multiply 10 by 4, and the product, 40, will be the number of teeth in the gear.

Number of Teeth required, outside diameter and diametral pitch given. Multiply the outside diameter by diametral pitch and subtract 2. *Example :* If the whole diameter is 10½ and the diametral pitch is 4, multiply 10½ by 4, and the product, 42 less 2, or 40, is the number of teeth.

Pitch Diameter required, number of teeth and diametral pitch given. Divide number of teeth by diametral pitch. *Example :* If the number of teeth is 40 and the diametral pitch is 4 divide 40 by 4, and the quotient, 10, is the pitch diameter.

Outside Diameter or size of gear blank required, number of teeth and diametral pitch given. Add 2 to number of teeth and divide by diametral pitch. *Example :* If the number of teeth is 40 and the diametral pitch is 4, add 2 to the 40, making 42, and divide by 4 ; the quotient, 10½, is the whole diameter of the gear or blank.

Thickness of Tooth at Pitch Line required. Divide circular pitch by 2, or 1·57 by diametral pitch. *Example :* If the circular pitch is 1·047 in., or diametral pitch is 3, divide 1·047 by 2, or 1·57 by 3, and the quotient, ·523, is the thickness of tooth.

Whole Depth of Tooth required. Divide 2·157 by diametral pitch. *Example :* If the diametral pitch of a gear is 6, the whole depth is 2·157 divided by 6, which equals ·3595.

Whole Depth of Tooth is ·6866 of the circular pitch. *Example :* If the circular pitch is 2, the whole depth of tooth is ·6866 times 2, which equals 1·373.

Distance between Centres of two gears required. Add the number of teeth together and divide one-half the sum by diametral pitch. *Example :* If two gears have 50 and 30 teeth respectively, and are 5 pitch, add 50 and 30, making 80 ; divide by 2, and then divide the quotient, 40, by the diametral pitch, 5, and the result, 8 in., is the centre distance.

Horse Powers of Machine-Cut Spur Gears.

(Messrs. Crofts, Ltd., Bradford, England.)

Approximate Horse Powers transmitted by Cast-iron Machine-cut Spur Gears working under favourable conditions respecting lubrication and loading.

For Intermittent and Shock Loads these Tables do not apply.

For Horse Power of Steel Gear Wheels multiply Powers in Table below by 2·2.

8 D.P. 1½″ WIDTH OF FACE

Number of Teeth in Wheel	REVOLUTIONS PER MINUTE OF GEAR WHEEL											
	50	60	70	80	90	100	150	200	250	300	350	400
40	·70	·84	·92	·97	1·10	1·20	1·40	1·70	2·00	2·30	2·50	2·70
60	1·00	1·10	1·20	1·35	1·40	1·50	1·90	2·30	2·60	3·00	3·20	3·40
80	1·20	1·35	1·50	1·60	1·70	1·90	2·40	2·90	3·20	3·50	3·70	3·90
100	1·50	1·70	1·90	2·00	2·10	2·20	2·80	3·30	3·60	3·80	4·00	—
120	1·60	1·80	2·00	2·15	2·30	2·50	3·10	3·60	3·90	4·10	—	—

6 D P. 1¾″ WIDTH OF FACE

Number of Teeth in Wheel	REVOLUTIONS PER MINUTE OF GEAR WHEEL											
	50	60	70	80	90	100	150	200	250	300	350	400
40	1·40	1·56	1·64	1·82	1·96	2·10	2·78	3·32	3·81	4·21	4·58	4·87
60	1·81	2·09	2·26	2·50	2·68	2·88	3·70	4·37	4·93	5·41	5·72	5·87
80	2·26	2·59	2·81	3·12	3·28	3·55	4·52	5·23	5·76	6·17	6·37	—
100	2·72	3·01	3·31	3·59	3·83	4·17	5·12	5·63	6·06	—	—	—
120	3·01	3·40	3·76	4·08	4·33	4·60	5·58	6·18	—	—	—	—

5 D.P. 2¼″ WIDTH OF FACE

Number of Teeth in Wheel	REVOLUTIONS PER MINUTE OF GEAR WHEEL											
	50	60	70	80	90	100	150	200	250	300	350	400
40	2·38	2·59	2·85	3·10	3·38	3·69	4·74	5·63	6·43	7·02	7·56	8·04
60	3·22	3·56	4·06	4·32	4·68	5·05	6·36	7·44	8·24	8·91	9·25	9·60
80	3·88	4·44	4·85	5·32	5·80	6·08	7·65	8·70	9·35	9·92	—	—
100	4·64	5·20	5·75	6·15	6·60	7·04	8·67	9·45	—	—	—	—
120	5·24	5·86	6·45	6·98	7·42	7·76	9·18	10·00	—	—	—	—

4 D.P. 2¾″ WIDTH OF FACE

Number of Teeth in Wheel	REVOLUTIONS PER MINUTE OF GEAR WHEEL											
	50	60	70	80	90	100	150	200	250	300	350	400
40	4·12	4·65	5·10	5·70	5·87	6·50	8·30	9·80	11·05	12·10	12·80	13·25
60	5·55	6·40	7·05	7·65	8·23	8·72	11·12	12·60	13·68	14·28	—	—
80	7·04	7·87	8·70	9·45	10·10	10·65	12·90	14·30	—	—	—	—
100	8·14	9·07	10·10	10·70	11·50	12·00	14·20	—	—	—	—	—
120	9·05	9·55	11·05	11·80	12·70	13·20	15·00	—	—	—	—	—

(Cast-iron Lubricated Gear Wheels under favourable conditions)

3½ D.P. 3″ WIDTH OF FACE

Number of Teeth in Wheel	REVOLUTIONS PER MINUTE OF GEAR WHEEL											
	50	60	70	80	90	100	150	200	250	300	350	400
40	5·60	6·37	7·10	7·53	8·23	8·80	11·40	13·35	14·81	15·85	16·61	17·31
60	7·65	8·62	9·42	10·30	11·22	11·95	14·70	16·62	17·75	—	—	—
80	9·45	10·55	11·62	12·70	13·50	14·30	17·00	18·55	—	—	—	—
100	11·00	12·35	13·32	14·42	15·25	15·90	18·35	—	—	—	—	—
120	12·45	13·75	15·10	15·72	16·72	17·30	—	—	—	—	—	—

3 D.P. 3½″ WIDTH OF FACE

Number of Teeth in Wheel	REVOLUTIONS PER MINUTE OF GEAR WHEEL											
	50	60	70	80	90	100	150	200	250	300	350	400
40	8·42	9·40	10·45	11·62	12·40	13·22	16·83	19·46	21·42	22·62	23·82	—
60	11·52	12·92	14·38	15·66	16·52	17·47	21·62	23·42	—	—	—	—
80	14·21	15·82	17·40	18·50	19·92	20·90	24·30	—	—	—	—	—
100	16·30	17·60	18·90	21·00	22·20	23·20	—	—	—	—	—	—
120	18·40	20·20	21·60	22·90	24·00	24·70	—	—	—	—	—	—

2½ D.P. 4″ WIDTH OF FACE

Number of Teeth in Wheel	REVOLUTIONS PER MINUTE OF GEAR WHEEL											
	50	60	70	80	90	100	150	200	250	300	350	400
40	13·10	14·60	16·25	17·40	19·00	20·00	25·00	28·60	31·20	32·70	—	—
60	18·00	20·00	21·90	23·80	25·30	26·60	31·60	34·50	—	—	—	—
80	21·70	24·40	26·50	28·20	30·00	32·00	36·00	—	—	—	—	—
100	25·00	28·00	30·00	32·00	34·00	36·00	—	—	—	—	—	—
120	28·00	31·00	33·00	35·00	37·00	38·00	—	—	—	—	—	—

2 D.P. 4½″ WIDTH OF FACE

Number of Teeth in Wheel	REVOLUTIONS PER MINUTE OF GEAR WHEEL											
	50	60	70	80	90	100	150	200	250	300	350	400
40	21·40	24·10	26·50	28·50	30·60	32·50	40·00	43·70	—	—	—	—
60	28·50	31·90	35·00	37·20	39·70	41·70	47·00	—	—	—	—	—
80	34·90	38·30	41·00	43·60	47·00	—	—	—	—	—	—	—
100	39·00	42·70	45·40	47·30	48·60	—	—	—	—	—	—	—
120	43·30	46·00	48·00	50·50	—	—	—	—	—	—	—	—

2 D.P. WIDTH OF FACE

Number of Teeth in Wheel	REVOLUTIONS PER MINUTE OF GEAR WHEEL											
	50	60	70	80	90	100	150	200	250	300	350	400
40	27·40	30·80	33·90	36·50	39·10	41·60	51·20	56·00	—	—	—	—
60	36·50	40·70	44·70	47·60	50·70	53·50	60·00	—	—	—	—	—
80	44·50	49·00	52·50	55·70	60·00	—	—	—	—	—	—	—
100	50·00	54·60	58·00	60·50	62·20	—	—	—	—	—	—	—
120	55·40	59·00	61·60	64·50	—	—	—	—	—	—	—	—

Formulas
FOR
Determining the Dimensions of Gears by Diametral Pitch.

Let P denote diametral pitch, or the number of teeth to one inch of diameter of pitch circle.

„ D' „ diameter of pitch circle.
„ D „ whole diameter.
„ D''' „ bottom diameter
„ N „ number of teeth.
„ V „ velocity.
} *Larger Wheel*

„ d' „ diameter of pitch circle.
„ d „ whole diameter.
„ d''' „ bottom diameter.
„ n „ number of teeth.
„ v „ velocity.
} *Smaller Wheel*

} These wheels run together.

„ a „ distance between centres of the two wheels.
„ b „ number of teeth in both wheels.
„ t „ thickness of tooth or cutter on pitch circle.
„ D'' „ working depth of tooth.
„ f „ amount added to depth of tooth for rounding the corners and for clearance.
„ $D''+f$ „ whole depth of ooth.
„ π „ constant 3·1416.
„ P' „ circular pitch or distance from the centre of one tooth to the centre of the next on pitch circle.

The examples placed opposite the formulas following are for a single wheel of 12 pitch, 6·166 in. or $6\frac{2}{12}$ in diameter, etc., and in the case of the two wheels the larger has the *same* dimensions. The velocities are respectively 1 and 2.

For a Single Wheel

FORMULAS. EXAMPLES.

$P = \frac{N+2}{D} = \frac{72+2}{6\cdot166}$ or $\frac{72+2}{6\frac{2}{12}} = 12.$ 1

$P = \frac{N}{D'} = \frac{72}{6} = 12.$ 2

$D' = \frac{D \times N}{N+2} = \frac{6\cdot166 \times 72}{72+2} = 6.$ 3

$D' = \frac{N}{P} = \frac{72}{12} = 6$ 4

$N = PD' = 12 \times 6 = 72$ 5

$N = PD - 2 = 12 \times 6\cdot166 - 2$, or $12 \times 6\frac{2}{12} - 2 = 72$ 6

$D = \frac{N+2}{P} = \frac{72+2}{12} = 6\cdot166$, or $6\frac{2}{12}$ 7

$D = D' + \frac{2}{P} = 6 + \frac{2}{12}$, or $6 + \cdot166 = 6\cdot166$ 8

$D''' = \frac{N - 2\cdot314}{P} = \frac{72 - 2\cdot314}{12} = 5\cdot807$ 9

$D''' = D - 2(D''+f) = 6\cdot166 - \cdot3596 = 5\cdot807$ 10

FORMULAS. EXAMPLES.

$t = \frac{1{\cdot}57}{P} = \frac{1{\cdot}57}{12} = {\cdot}130$. 11

$D'' = \frac{2}{P} = \frac{2}{12} = {\cdot}166$, or $\frac{2}{12}$ 12

$f = \frac{t}{10} = \frac{{\cdot}130}{10} = {\cdot}013$ 13

$D'' + f = {\cdot}166 + {\cdot}013 = {\cdot}179$ 14

$P' = \frac{\pi}{P} = \frac{3{\cdot}1416}{12} = {\cdot}262$ 15

$P = \frac{\pi}{P'} = \frac{3{\cdot}1416}{{\cdot}262} = 12$ 16

For a Pair of Wheels

FORMULAS. EXAMPLES.

$b = 2\,a\,P = 2 \times 4{\cdot}5 \times 12 = 108$ 17

$n = \frac{bV}{v+V} = \frac{108 \times 1}{3} = 36$ 18

$N = \frac{nv}{V} = \frac{36 \times 2}{1} = 72$ 19

$n = \frac{NV}{v} = \frac{72 \times 1}{2} = 36$ 20

$N = \frac{bv}{v+V} = \frac{108 \times 2}{3} = 72$ 21

$n = \frac{PD'V}{v} = \frac{12 \times 6 \times 1}{2} = 36$ 22

$V = \frac{nv}{N} = \frac{36 \times 2}{72} = 1$ 23

$v = \frac{NV}{n} = \frac{72 \times 1}{36} = 2$ 24

$v = \frac{PD'V}{n} = \frac{12 \times 6 \times 1}{36} = 2$ 25

$D = \frac{2a(N+2)}{b} = \frac{2 \times 4{\cdot}5 \times (72+2)}{108} = 6{\cdot}166$ 26

$d = \frac{2a(n+2)}{b} = \frac{2 \times 4{\cdot}5 \times (36+2)}{108} = 3{\cdot}166$ 27

$a = \frac{b}{2P} = \frac{108}{2 \times 12} = 4{\cdot}5$ 28

$D = \frac{2av}{v+V} = \frac{2 \times 4{\cdot}5 \times 2}{3} = 6$ 29

$d' = \frac{2aV}{v+V} = \frac{2 \times 4{\cdot}5 \times 1}{3} = 3$ 30

$a = \frac{D'+d'}{2} = \frac{6+3}{2} = 4{\cdot}5$ 31

FRICTION OF SHAFTS.

Friction of Shafts.—Friction is governed by pressure, and is independent of surface, and the friction of a revolving body is nearly independent of its velocity. Shafting should be made as light as possible consistent with strength and stiffness, because the friction of shafts on their bearings is directly proportional to their weight. The friction of any two surfaces when no lubricant is interposed, is directly proportional to the force with which they are pressed together, and is entirely independent of the extent of surfaces in contact; so that the power absorbed by friction does not increase with the length of bearing. But when the surfaces in contact are lubricated, then the amount of friction depends upon the adhesive nature of the lubricant, and the effect will be in proportion to the extent of the surfaces between which it is interposed. Therefore, to diminish the power absorbed by friction as much as possible, and to secure easy working, it is important to use the best quality of oil.

Machinery Oils.—The best lubricant for high-speed machinery under light pressure is sperm oil; for heavy machinery at low speeds, rape oil; for general machinery, olive oil; for general light machinery, equal parts of sperm oil and good mineral oil; for heated machinery and pistons, neatsfoot oil mixed with plumbago; for Diesel engines, mineral oil.

Resistance due to Friction.—The amount of friction between two surfaces, is found by multiplying the weight or force in lbs. with which they are pressed together by the co-efficient of friction in the following table. The co-efficient of friction, means the resistance from friction, between two surfaces, due to a pressure of 1 lb.

The power absorbed by Friction, is found by multiplying the resistance due to friction, found by the above rule, by the space in feet passed through by one surface upon the other.

The power absorbed by friction in footpounds, on round shafts in one revolution, is found thus: Multiply the diameter of the shaft in inches by ·26, and by the product of the weight of the shaft by the co-efficient of friction; which will give the power absorbed for one revolution in foot-lbs.

The weight of pulleys and the load due to the pull of belts must be added to the weight of the shafting in calculating the power absorbed by friction. Shafting 2½ inches diameter, making 100 revolutions per minute with the ordinary proportional number of pulleys upon it, but without belts on, requires about 1 horse-power to drive it alone, for every 120 feet in length.

Horse-power absorbed by Friction on a revolving shaft with parallel necks is found thus: Multiply the power absorbed in one revolution, found by the last rule, by the number of revolutions per minute, and divide the product by 33,000.

The co-efficients of Friction for ordinary shafts and shafting, under ordinary conditions, deduced from the experiments on friction, are given in the following Table.

Table 20.—FRICTION OF SHAFTING AND SHAFTS IN MOTION UPON WELL-FITTED AND EFFICIENTLY LUBRICATED BEARINGS.

Surfaces in Contact.	Revolutions per Minute.		
	150	300	400
	Coefficients of Friction.		
Wrought Iron on Gun Metal Bearings.	·002	·003	·004
Wrought Iron on Cast Iron Bearings.			
Cast Iron on Cast Iron Bearings.			
Cast Iron on Gun Metal Bearings.			
Gun Metal on Gun Metal Bearings.	·003	·004	·006
These data apply to Horizontal Shafting with Parallel Necks. The Friction of Upright Shafting is 20 per cent. less.			

The above co-efficients × the Nominal Load = Nominal Friction Resistance per square inch of Bearing. The Nominal Load per square inch, is the total load on the Bearing divided by the product of the diameter in inches, and the length in inches of the Bearing.

SHAFTING.

Strain on Shafting.—Shafting is subject to two forces—twisting and bending. The twisting force is due to the power transmitted, and increases in proportion to the power; but decreases in proportion to the velocity. The bending force is due to the weight of the shaft, also to the strain of belts upon it, and the weights of pulleys and gearing. When the weight is distributed along the length of a shaft, it only causes one-half the quantity of deflection that it would if placed on the middle of the shaft.

Torsional Strength of Shafts.—The strength of round shafts to resist being twisted asunder is in proportion to the cubes of their diameters, and is independent of the length. A bar of wrought-iron of average quality, 1 inch diameter, is twisted asunder by a weight of 800 lbs. at the end of a lever 12 inches long, or at the pitch-line of a wheel 24 inches diameter; and a cast-iron shaft is twisted asunder by a weight of 450 lbs. applied in the same way. From these data, any other diameter can be calculated, the strength increasing as the cube of the diameter. But the power of a bar to resist a load is in inverse proportion to the length of lever; thus a lever 24 inches long, only requires one-half the weight to break a bar, that would be required with a lever 12 inches long.

Safe Torsional Strength of Shafts.—To find the safe working strain in lbs. that may be put on to the circumference of wheels and pulleys fixed to shafts, a common rule is: multiply the cube of the diameter of the shaft in inches, by 1765 for wrought iron, or by 980 for cast iron, and divide the product by the radius of the wheel or pulley in inches. If a lever or crank is employed, use the length of the lever or crank as a divisor in the above rule. For steel shafts, use a multiplier of 2,500.

Hollow Shafts.—To find the relative value for transmitting power of a hollow shaft, from the cube of the outside diameter deduct the cube of the inside diameter; the result will be the relative value of that shaft.

The Diameter of Hollow-Shafting of Compressed-Steel may be found approximately by this rule.—Multiply the indicated horse-power the shaft is required to transmit by 90, divide the product by the number of revolutions per minute, and the cube root of the quotient will be the *external* diameter of the shaft in inches ; the *internal* diameter of the shaft to be = the external diameter of the shaft multiplied by ·56.

Torsional Stiffness of Shafting.—Stiffness in shafting is more important than strength; when the length of a line of shafting does not exceed 100 feet, the tendency is greater to bend than to twist ; but a long line of shafting of from 140 to 200 feet long is very elastic, and when driving machinery at the extreme end, it has a great tendency to twist, so much so, that the driving end may make nearly a revolution before the extreme end begins to turn. A shaft that bends or yields to the strain, will take more power to keep it in motion, than would be required by a heavier shaft, stiff enough to resist the same strain. Consequently, when long lines of shafting are employed, sufficient stiffness should be given to them to withstand the torsion at the extreme end, by making the lengths of shafting increase in diameter towards the driving end, each length being made stiff in proportion to the anticipated stress. A shaft may be strong enough to resist the twisting strain, but may not be stiff enough to drive steadily without vibration. The torsional stiffness of shafting varies as the fourth power of the diameter divided by the length. Shafting of 5 inches diameter and upwards, which is strong enough to resist the torsional strain, will be stiff enough to work properly ; but, below that size, a larger shaft should be used than is necessary to resist the torsional strain, in order to ensure proper stiffness and steady driving power.

RELATIVE STRENGTH OF METALS TO RESIST TORSION, THAT OF WROUGHT-IRON BEING 1.

Wrought Iron	1·00	Brass	·27
Cast Iron	·90	Copper	·25
Cast Steel	1·95	Tin	·13
Gun Metal	·35	Lead	·10

POWER OF SHAFTS.

Size of Crankshafts.—The size of a crankshaft should be determined by the maximum strain it has to resist, which may be found as follows:—

1. *Find the maximum of pressure on the crank* exclusive of friction, thus : multiply the area of the piston in square inches, by the pressure of steam in lbs. per square inch.

2 *Find the breaking strength in lbs.* by multiplying the pressure on the crank, found by the last rule, by the number of times the breaking strength is to exceed the working strength—say 6.

3. *Find the strain in lbs. due to the leverage of the crank*, thus: divide the constant number 800 for a wrought-iron crankshaft, or 450 for cast-iron, or 1100 for steel, by the length of the crank in feet.

4. Divide the breaking strength by the strain due to the leverage of the crank found by the above rules, and the cube root of the quotient will be the diameter in inches of the shaft required.

The Nominal Horse-power of shafts may be found by the following *Rule*, thus: multiply the cube of the diameter of the shaft in inches by the number of revolutions per minute, and divide the product by 170 for wrought-iron, or by 260 for cast-iron, or by 85 for steel.

To find the diameter of a shaft suitable for a given nominal horse-power, multiply the horse-power by 170 for wrought-iron, or by 260 for cast-iron, or by 85 for steel, and divide the product by the number of revolutions per minute; the cube root of the quotient will be the diameter of the shaft in inches.

To find the speed necessary for a given nominal horse-power, with a given size of shaft, multiply the horse-power by 170 for wrought-iron, or by 260 for cast-iron, or by 85 for steel, and divide the product by the cube of the diameter of the shaft in inches: the quotient will be the number of revolutions per minute. These rules for nominal horse-power apply to shafts above 4½ inches diameter; below that size something must be added to the result given by the above rules, if a long shaft is employed, in order to obtain sufficient stiffness, which is of more importance than strength in a long shaft, and the proper size of shaft may be found from Table 21, which has been deduced from cases in practice.

The Nominal Horse-power of Crankshafts may be found thus:—Multiply the nominal horse-power of ordinary shafts found by the above rules, by 1·57 for a single engine, or by 1·11 for a pair of engines coupled at right angles.

Power of Crane Shafts of Wrought-Iron.—When shafts work at very slow speeds and lift heavy weights, such as crane shafts, the safe working load should not exceed $\frac{1}{10}$th of the breaking weight, and the diameter of the shaft must be proportioned to the strain, according to the following rule. A bar of wrought-iron, 1 inch diameter, is twisted asunder by a weight of 800 lbs. applied at the end of a lever 12 inches long, from the centre of the shaft, therefore—

1. Divide the constant number 800 by the length of lever, or radius of the wheel in feet, and the quotient will be the breaking strain in lbs.

2. Multiply the weight or strain on the shaft in lbs. by 10 (the factor of safety), and divide the product by the breaking strain, and the cube root of the quotient will be the proper diameter in inches of the shaft of wrought-iron.

Table 21.—Nominal Horse-power of Wrought-Iron, Cast-Iron, and Steel Shafts.

Diameter of the Shaft in Inches.	Wrought-Iron Shaft.	Cast-Iron Shaft.	Steel Shaft.	Diameter of the Shaft in Inches.	Wrought-Iron Shaft.	Cast-Iron Shaft.	Steel Shaft.
	Nominal Horse Power at one Revolution per Minute.	Nominal Horse Power at one Revolution per Minute.	Nominal Horse Power at one Revolution per Minute.		Nominal Horse Power at one Revolution per Minute.	Nominal Horse Power at one Revolution per Minute.	Nominal Horse Power at one Revolution per Minute.
1	·001	·0006	·002	4	·34	·21	·51
1⅛	·002	·001	·003	4¼	·44	·29	·66
1¼	·003	·002	·005	4½	·56	·36	·84
1⅜	·004	·003	·006	4¾	·64	·41	·96
1½	·006	·004	·009	5	·73	·47	1·09
1⅝	·009	·006	·013	5¼	·85	·54	1·27
1¾	·013	·008	·019	5½	·97	·62	1·45
1⅞	·016	·010	·024	6	1·27	·81	1·91
2	·021	·013	·031	6½	1·61	1·03	2·41
2⅛	·027	·017	·041	7	2·0	1·28	3·01
2¼	·035	·024	·052	7½	2·43	1·56	3·64
2⅜	·046	·029	·069	8	3·0	1·92	4·51
2½	·053	·034	·079	9	4·22	2·71	6·33
2⅝	·066	·042	·099	10	5·88	3·85	8·82
2¾	·077	·049	·115	11	7·83	5·03	11·74
2⅞	·095	·061	·142	12	10·16	6·53	15·24
3	·11	·07	·160	13	12·91	8·28	19·36
3⅛	·14	·09	·21	14	16·14	10·37	24·61
3¼	·16	·1	·24	15	19·85	12·76	29·77
3⅜	·19	·12	·28	16	24·09	15·48	36·13
3½	·22	·13	·32	17	28·9	18·57	42·13
3¾	·28	·17	·41	18	34·3	22·05	51·42

To find the nominal horse-power of a shaft, multiply the horse-power given in this table by the nnmber of revolutions per minute at which the required shaft is to work. This table applies to all shafting and shafts, except crane shafts and crank shafts.

Actual or Indicated Horse-power of Shafts.—The actual or indicated horse-power, which a shaft is capable of properly transmitting, may in a general way, be taken at from 60 to 100 per cent. more than the nominal horse-power found from the above Table.

Distance between the Bearings of Shafting.—The distance between the bearings, should be arranged to suit the load to be carried, but in a general way, the distance between the bearings of shafting carrying its own weight only, and also of shafting carrying the usual proportion of pulleys or gearing, may be according to the table No. 22. Couplings and gearing to be fixed close to bearings.

Pressure on the Necks, or Journals of Shafts.—The pressure on the necks of shafts, should not exceed 350 lbs. per square inch, measured on the surface or circumference, for necks of ordinary length; for extra long necks, it may in unavoidable cases be from 500 to 600 lbs. per square inch. Should the pressure exceed the latter amount, the surfaces of the neck and bushes will be brought into such close contact, that the surfaces cannot properly retain oil, and the bearings will be liable to heat and cut.

Corners of Shaft-Necks.—The corners of necks of shafts should always be rounded, because square corners reduce the strength of the neck to resist strains, to the extent of one-fifth.

Actual Horse-power of Shafts.—To find the actual horse-power of a shaft, multiply the load by the distance in feet, through which it travels in one minute, and divide the product by 33,000.

To find the load, multiply the constant number 800 for wrought-iron, or 450 for cast-iron, or 1100 for steel, by the cube of the diameter of the shaft, in inches, and the product will be the breaking weight in lbs., which divide by 6 (the factor of safety): the result gives the safe working load in lbs.

To find the distance through which the load travels, multiply the circumference of the pitch circle of a wheel, or the circumference of a pulley, or circle described by a lever or crank, in feet, by the number of revolutions per minute.

Crank Shafts of Engines.—A crank shaft has to resist a varying strain, and its strength must be in proportion to the maximum strain upon it.

The average pressure upon a crank, is found thus: multiply the pressure upon the piston, by the distance through which it travels in making a double stroke, and divide the product by the distance through which the crankpin travels in the same time. The distance the piston travels equals twice the diameter of the circle described by the crankpin; the distance the crank travels is 3·1416 times the diameter of the circle described by the crankpin; therefore, the mean strain on the piston $= \frac{3\cdot1416}{2} = 1\cdot57$ times the driving pressure upon the crankpin. The power exerted by the piston, varies with every change of position of the crank, but the varying strain on the crankshaft is equalised by the fly-wheel. But, that part of the crankshaft between the crank and the fly-wheel, has a greater strain upon it in the ratio of 1·57 to 1 than the part of the shaft behind the flywheel.

The Speed of Shafting for driving machine-tools and general machinery is usually from 90 to 100 revolutions per minute, and for driving wood-working machinery it is generally 240 revolutions per minute.

Hire of Steam Power.—The price charged for the hire of steam power and use of shafting is usually £20 per indicated horse-power per annum. The price charged for the hire of a portable engine is usually £25 per nominal horse-power per annum.

TABLE 22.—DISTANCE BETWEEN THE BEARINGS OF SHAFTING.

Diameter of the shafting, in inches	1¼	1½	1¾	2	2¼	2½	3	3½	4	4½	5	6	7	8	9	10
Distance between the bearings, for shafting carrying its own weight only, in feet	6	7	8	9	10	11	13	14	15	16	17	20	22	24	26	28
Distance between the bearings, for shafting carrying the ordinary proportion of pulleys, &c., in feet	3	4	5	7	8	9	10	10½	11	12	13	15	16	18	19	20

TABLE 23.—WEIGHT OF SHAFTING PER FOOT IN LENGTH, AND THE AVERAGE WEIGHT OF COLLARS, COUPLINGS AND PLUMMER BLOCKS IN LBS.

Diameter of shafting, in inches .	1¼	1½	1¾	2	2¼	2½	2¾	3	3½	4	4½	5	6	7	8	9	10
Weight of plain wrought-iron shafting, per foot in length, in lbs. .	4·09	5·89	8·02	10·5	13·3	16·5	19·8	23·6	32·2	42	53·2	66	95	130	168	213	264
Weight of collars welded on, for necks, per *pair*, in lbs. . .	½	1	2	3	4	5	6	7	8	12	16	21	28	35	42	50	60
Weight of loose collars with set screws, per *pair*, in lbs. . .	3	5	6	7	8	9	10	12	14	16	20	28	35	47	53	64	80
Weight of cast-iron flange coupling, complete with bolts, in lbs. .	17	23	38	54	74	96	109	125	165	234	289	322	406	466			
Weight of cast-iron muff coupling, for shafting, without swelled ends, in lbs.	14	17	21	31	41	62	70	94	106	179	202	241	396	476			
Weight of plummer block, complete with brasses and bolts, in lbs.	10	15	19	24	33	40	48	56	76	99	124	156	224	324	420	518	636

The dimensions and weight of couplings for shafting, are given at pp. 145 to 147, and of plummer blocks, at p. 149.

CAST-IRON COUPLINGS FOR SHAFTS.

Cast-Iron Flange-Couplings, Fig. 113.—In order to keep the shafts in line with each other, the end of one shaft projects from one half-coupling to a length equal to ¼ the thickness of one flange, and enters the other half-coupling. Each half-coupling is keyed on with a sunk key, and afterwards turned true in its place. The bolt-heads and nuts are sometimes countersunk, in which cases the flanges must be made proportionally thicker. A shafting-hanger, with adjustable bearing, is shown in Fig. 114.

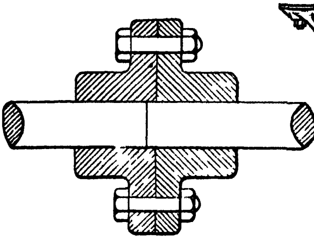


Fig. 113 – Flange Coupling

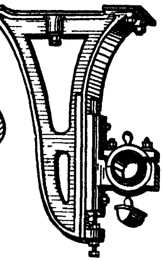


Fig. 114.—Hanger

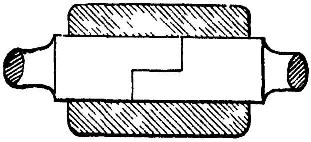


Fig 115 Muff-Coupling.

Table 24.—Proportions of Cast-Iron Flange-Couplings (Fig. 113).

Diameter of Shaft.	Diameter of Flange.	Thickness of each Flange	Diameter of Boss.	Length of Boss beyond the Flange.	Diameter of Circle of the Centres of Bolts.	Diameter of Bolts.	Number of Bolts.	Keyway. Wide	Keyway. Deep	Weight of Coupling complete with Bolts. cwt.	qr.	lb
Inches.	Inches.	Inches.	Inch.	Inches.	Inches.	Inch.		Inch	Inch	cwt.	qr.	lb
1½	7	⅞	3	1⅞	5¼	¾	3	7/16	3/16	0	0	23
1¾	7¾	1	3½	2	5¾	¾	3	½	3/16	0	1	10
2	8¼	1⅛	4	2⅛	6¼	⅞	4	⅝	¼	0	1	26
2¼	9¼	1 3/16	4½	2¼	7	⅞	4	⅝	¼	0	2	18
2½	10	1¼	5	2½	7½	⅞	4	¾	5/16	0	3	12
2¾	10½	1⅜	5½	2⅝	8	1	4	¾	5/16	0	3	25
3	11¼	1½	6	3	8¾	1	4	⅞	5/16	1	0	13
3½	13	1⅝	7	3⅜	10	1	4	1	⅜	1	1	25
4	14½	1¾	8	3¾	11½	1	6	1⅛	⅜	2	0	10
4½	16	1⅞	9	4⅛	13	1⅛	6	1¼	⅜	2	2	9
5	17¾	2	10	4½	14	1¼	6	1⅜	½	2	3	14
6	20½	2¼	12	5¼	16¼	1⅜	6	1⅝	⅝	3	2	14
7	23	2⅜	14	6⅛	18	1½	6	1⅞	⅝	4	0	18

Muff or Solid Cast-Iron Couplings.—For best work, the ends of the shafts should be swelled and joined together with a half-lap joint, which takes the driving strain, as shown in Fig. 115. Taper of joint, 1 inch per foot. A hollow key is used to key on the coupling.

Table 25.—PROPORTIONS OF MUFF-COUPLINGS, FOR SHAFTS WITH HALF-LAP JOINT (as shown in Fig. 115).

Diameter of the Shaft.	Diameter of the Swell.	Length of the Swell.	Length of Lap.	Diameter of Coupling.	Length of Coupling.	Keyway.		Weight of Coupling.		
						Width.	Depth.			
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	cwt.	qr.	lb.
1½	2½	3⅞	1⅜	5	7	¾	5/16	0	0	25
1¾	3	4½	1½	5½	8	⅞	5/16	0	1	5
2	3¼	4¾	1¾	6	8½	⅞	5/16	0	1	14
2¼	3½	5⅛	2	6½	9	1	⅜	0	1	25
2½	4	5⅝	2¼	7½	10	1⅛	⅜	0	2	22
2¾	4½	6⅛	2⅜	8	11	1¼	⅜	0	3	12
3	4¾	6¾	2½	9	12	1⅜	½	1	1	0
3½	5¼	7¼	3	10	13	1½	½	1	2	20
4	6	8	3½	11	14	1⅝	⅝	2	0	4
4½	6½	8½	4	12	15	1¾	⅝	2	2	0
5	7¼	9	4¼	13	16	1⅞	⅝	3	1	10
6	9	10½	5	16	18	2⅜	¾	5	2	18
7	10½	12	6	18	21	2¾	⅞	7	3	18

Muff-Couplings for Shafts with Butt-Ends, Fig. 116.—Where price is an object, muff-couplings are used with shafts without swells, and the ends of the shafts butt together, instead of being half-lapped.

Table 26.—MUFF-COUPLINGS FOR SHAFTS WITH BUTT-ENDS (as shown in Fig. 116).

Diameter of the Shaft.	Diameter of Coupling.	Length of Coupling.	Keyway.		Weight of Coupling.		
			Width.	Depth.			
Inches.	Inches.	Inches.	Inches.	Inches.	cwt.	qr.	lb.
1½	4½	6¾	7/16	3/16	0	0	17
1¾	5	7½	½	3/16	0	0	21
2	5¼	7⅞	⅝	¼	0	1	3
2¼	5½	8¼	⅝	¼	0	1	13
2½	6¼	9⅜	¾	5/16	0	2	6
2¾	6½	9¾	¾	5/16	0	2	14
3	7¼	10⅞	⅞	5/16	0	3	10
3½	8	12	1	⅜	0	3	22
4	9	13½	1⅛	⅜	1	2	10
4½	9½	14¼	1¼	⅜	1	3	6
5	10¼	15⅜	1⅜	½	2	0	17
6	12	18	1⅝	⅝	3	2	4
7	13	19½	1⅞	11/16	4	1	0

The Cast-Iron Claw-Couplings, shown in Fig. 116, are of strong construction.

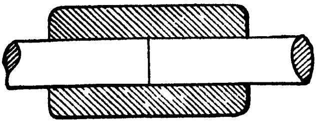


Fig 116.—Muff Coupling.

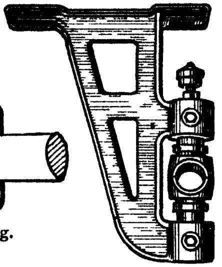


Fig. 117.—Hanger

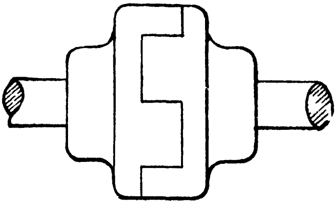


Fig 118.—Claw Coupling

A shafting-hanger, with adjustable swivelling bearings, is shown in Fig. 117.

Table 27.—Proportions of Cast-Iron Claw-Couplings (Fig. 118)

Diameter of Shaft where Coupling is fitted	Outside Diameter of Claw.	Length of Claw.	Thickness of Flange at back of Recess.	Diameter of the Boss.	Length of Boss beyond the Flange	Extra Length to be added to one half of the Coupling when it is required for a Disengaging Coupling.		Size of Keyway.	
						Width of Groove	Thickness of end Collar	Width.	Depth
Inches	Inches.	Inches.	Inches	Inches	Inches	Inches	Inches	Inches.	Inches
3	7½	1⅞	1	5¾	2	1¾	⅞	⅞	5/16
4	10	2½	1¼	7¼	2½	1⅞	1	1⅛	⅜
5	12½	3⅛	1⅝	9½	3	2	1⅛	1⅜	½
6	15	3¾	2	11½	3½	2⅛	1¼	1⅝	⅝
7	17½	4⅜	2⅜	13¼	4	2¼	1⅜	1⅞	⅝
8	20	4¾	2¾	14¾	4½	2⅜	1½	2⅛	¾
9	22½	5⅝	3	16½	5	2½	1⅝	2⅜	¾
10	25	6¼	3½	18½	5½	2⅝	1¾	2⅝	¾
11	27½	6⅞	3¾	20½	6	2¾	1⅞	2¾	⅞
12	30	7½	4	21	6½	3	2	3	1
13	32½	8⅛	4¼	23	7	3⅛	2⅛	3¼	1
14	35	8¾	4½	25	7½	3¼	2¼	3½	1⅛
15	37½	9⅜	5	27	8	3½	2½	3¾	1¼

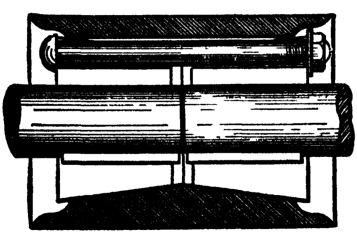


Fig. 119.—Friction-Cone Coupling

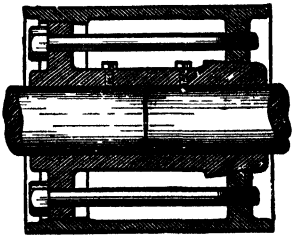


Fig. 120.—Friction-Cone Coupling.

Friction-Cone Couplings, two forms of which are shown in Figs. 119 & 120 are strong and efficient They may be also used as pulleys.

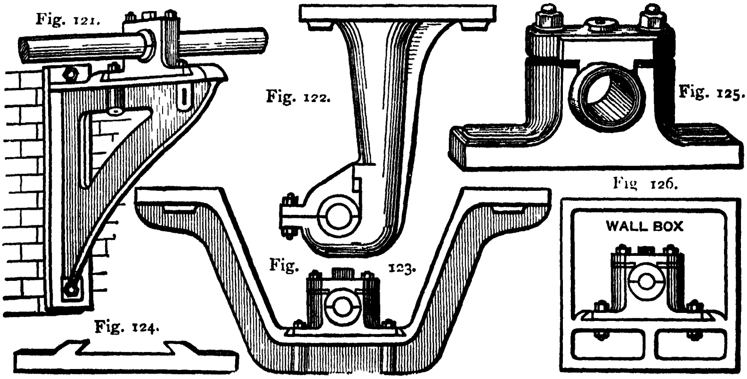
The proportions of Keys are given in the following Table:—

Table 28.—PROPORTIONS OF KEYS FOR WHEELS AND PULLEYS.

Diameter of Shaft.	SIZE OF KEY.		Depth sunk in Shaft.	Depth sunk in Wheel.	Diameter of Shaft.	SIZE OF KEY.		Depth sunk in Shaft.	Depth sunk in Wheel.
	Breadth.	Thickness.				Breadth.	Thickness.		
Inches.	Inch.	Inch.	Inch.	Inch.	Inches.	Inches.	Inches.	Inch.	Inches.
$\frac{5}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{16}$	$3\frac{1}{4}$	$\frac{7}{8}$	$\frac{1}{2}$	$\frac{3}{16}$	$\frac{5}{16}$
$\frac{3}{4}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{16}$	$\frac{1}{8}$	$3\frac{1}{2}$	1	$\frac{5}{8}$	$\frac{1}{4}$	$\frac{3}{8}$
$\frac{7}{8}$	$\frac{1}{4}$	$\frac{3}{16}$	$\frac{1}{16}$	$\frac{1}{8}$	$3\frac{3}{4}$	1	$\frac{5}{8}$	$\frac{1}{4}$	$\frac{3}{8}$
1	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{16}$	$\frac{3}{16}$	4	$1\frac{1}{8}$	$\frac{5}{8}$	$\frac{1}{4}$	$\frac{3}{8}$
$1\frac{1}{8}$	$\frac{5}{16}$	$\frac{1}{4}$	$\frac{1}{16}$	$\frac{3}{16}$	$4\frac{1}{2}$	$1\frac{1}{4}$	$\frac{5}{8}$	$\frac{1}{4}$	$\frac{3}{8}$
$1\frac{1}{4}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	5	$1\frac{3}{8}$	$\frac{3}{4}$	$\frac{1}{4}$	$\frac{1}{2}$
$1\frac{3}{8}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$5\frac{1}{2}$	$1\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{4}$	$\frac{1}{2}$
$1\frac{1}{2}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	6	$1\frac{5}{8}$	$\frac{7}{8}$	$\frac{1}{4}$	$\frac{5}{8}$
$1\frac{5}{8}$	$\frac{7}{16}$	$\frac{5}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$6\frac{1}{2}$	$1\frac{3}{4}$	$\frac{7}{8}$	$\frac{1}{4}$	$\frac{5}{8}$
$1\frac{3}{4}$	$\frac{1}{2}$	$\frac{5}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	7	$1\frac{7}{8}$	1	$\frac{3}{8}$	$\frac{5}{8}$
$1\frac{7}{8}$	$\frac{1}{2}$	$\frac{5}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$7\frac{1}{2}$	2	1	$\frac{3}{8}$	$\frac{5}{8}$
2	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{4}$	8	$2\frac{1}{8}$	$1\frac{1}{8}$	$\frac{3}{8}$	$\frac{3}{4}$
$2\frac{1}{8}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{4}$	$8\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{1}{8}$	$\frac{3}{8}$	$\frac{3}{4}$
$2\frac{1}{4}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{4}$	9	$2\frac{3}{8}$	$1\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$
$2\frac{3}{8}$	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{4}$	$9\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$
$2\frac{1}{2}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{16}$	$\frac{5}{16}$	10	$2\frac{5}{8}$	$1\frac{1}{4}$	$\frac{1}{2}$	$\frac{3}{4}$
$2\frac{5}{8}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{16}$	$\frac{5}{16}$	$10\frac{1}{2}$	$2\frac{3}{4}$	$1\frac{3}{8}$	$\frac{1}{2}$	$\frac{7}{8}$
$2\frac{3}{4}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{16}$	$\frac{5}{16}$	11	3	$1\frac{3}{8}$	$\frac{1}{2}$	$\frac{7}{8}$
$2\frac{7}{8}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{16}$	$\frac{5}{16}$	$11\frac{1}{2}$	$3\frac{1}{8}$	$1\frac{1}{2}$	$\frac{1}{2}$	1
3	$\frac{7}{8}$	$\frac{1}{2}$	$\frac{3}{16}$	$\frac{5}{16}$	12	$3\frac{1}{4}$	$1\frac{1}{2}$	$\frac{1}{2}$	1

The depth the key is sunk in the shaft or wheel is measured at the side of the key When keys are made with gib-heads, the depth and length of the gib-head should each be equal to the thickness of the key. Taper of keys, $\frac{3}{16}$ to $\frac{1}{4}$ inch per foot in length.

Hangers for Shafting are of various forms, several of which are shown in Figs. 114, 117 & 121–123.



Figs. 121–126.—Hangers for Shafting, Plummer-Blocks, Wall Box.

The proportions of Plummer-Blocks are given in the following Table:—

PLUMMER-BLOCKS.

TABLE 29.—PROPORTIONS OF PLUMMER-BLOCKS.

Diameter of Neck.	Length of Neck	Height to Centre.	Dimensions of Base.					Dimensions of Bushes.			Centres of Cap Bolts.	Diameter of Cap Bolts.	Weight of Plummer-Block Complete, with Gun Metal Bushes.		
			Length of Base.	Breadth of Base	Thickness of Base at End	Centres of Holding down Bolts in Base	Size of Bolt Holes in Base	Thickness of Bush at Side.	Thickness of Bush at Bottom.	Thickness of Flange of Bush					
Inches.	Inches	Inches	Inches	Inches.	Inches	Inches	Inches	Inches	Inches.	Inches	Inches.	Inches.	cwt	qr.	lb
1	1½	1⅜	7	1	¾	5	½ × 1	3/16	¼	¼	2	⅜	0	0	6
1¼	2	1¾	8	1½	⅞	6	⅝ × 1⅛	3/16	5/16	¼	2½	½	0	0	10
1½	2½	2	9	1¾	1	7	⅝ × 1¼	¼	⅜	⅜	3	⅝	0	0	15
1¾	3	2¼	9½	2¼	1⅛	7¼	¾ × 1⅜	¼	⅜	⅜	3½	⅝	0	0	19
2	3½	2½	10	2½	1¼	7½	⅞ × 1½	5/16	7/16	½	4	¾	0	0	24
2¼	3¾	2¾	11	2¾	1¼	8½	⅞ × 1½	5/16	7/16	½	4½	¾	0	1	5
2½	4	3	12	3	1⅜	9¼	1 × 1⅝	⅜	½	½	5	⅞	0	1	12
2¾	4¼	3¼	13	3¼	1½	10	1 × 1⅝	⅜	½	½	5⅜	⅞	0	1	20
3	5	3½	14	3¾	1⅝	11	1⅛ × 1¾	⅜	9/16	⅝	5¾	1	0	2	0
3¼	5¼	3⅝	14½	4	1⅝	11¼	1⅛ × 1¾	⅜	9/16	⅝	6⅛	1	0	2	10
3½	5½	3¾	15	4¼	1¾	11¾	1⅛ × 2	⅜	9/16	⅝	6½	1	0	2	20
3¾	5¾	4	15½	4½	1¾	12	1¼ × 2	⅜	9/16	⅝	7	1⅛	0	3	6
4	6	4¼	16	4½	1⅞	12½	1¼ × 2¼	7/16	⅝	¾	7½	1⅛	0	3	15
4¼	6¼	4½	17	4¾	1⅞	13½	1¼ × 2¼	7/16	⅝	¾	8	1⅛	0	3	24
4½	6½	4¾	18	5	2	14	1¼ × 2¼	½	11/16	¾	8½	1⅛	1	0	12
4¾	6¾	5	19	5¼	2⅛	14½	1⅜ × 2¼	½	11/16	¾	9	1¼	1	1	0
5	7	5¼	20	5¼	2¼	15½	1⅜ × 2½	½	¾	⅞	9¼	1¼	1	1	16
5¼	7¼	5½	21	5½	2⅜	16½	1½ × 2½	½	¾	⅞	9½	1¼	1	2	8
5½	7½	6	22	5¾	2½	17	1½ × 2½	½	13/16	⅞	10¼	1¼	1	3	0
6	8	6½	23	6¼	2¾	18	1⅝ × 2¾	⅝	⅞	⅞	11	1⅜	2	0	0
6½	9	7	24	7	3	19	1⅝ × 3	⅝	⅞	1	12	1½	2	1	24
							Four					Four			
7	10	7½	25	8	3⅛	20	1⅜ × 3	¾	1	1	13	1¼	2	3	16
8	11	8½	29	9	3¼	23	1⅝ × 3	¾	1⅛	1	14¾	1½	3	3	0
9	12	9½	30	10	3½	24	1¾ × 3¼	¾	1⅛	1	16¾	1⅝	4	2	14
10	14	10½	33	11¾	3¾	26	1⅞ × 3¼	⅞	1 3/16	1⅛	18½	1¾	5	2	20
11	15	11	34	12½	4	27	2 × 3½	⅞	1¼	1¼	20	1⅞	6	3	0
12	16	12	36	13½	4¼	28	2¼ × 3¾	⅞	1¼	1¼	22	2⅛	8	0	16
13	17	13	40	14¼	4½	32	2¼ × 4	1	1⅜	1⅜	24	2⅛	9	2	10
14	18	14	48	15	5	39	2⅜ × 4½	1	1½	1½	26	2¼	11	1	0

Thickness of Cap of Plummer-Block = the Diameter of the Neck Multipled by ·43 Plummer Blocks of 7 Inches Neck and upwards have 4 Bolts in the Cap and in the Base.

Wall-Plates for Plummer-Blocks should equal, in length, 7 times the diameter of the neck; in thickness = diameter of neck multiplied by ·4; in width = twice the diameter of neck, and the centres of the holding down bolts in same should = $5\frac{1}{2}$ times the diameter of the neck. Depth of boss for bolt-holes, and also the depth of the joggles for holding the wedge, should = three-fourths of the thickness of base of plummer-block. A saddle-plate is shown in Fig. 124.

DIAMETER AND SPEED OF PULLEYS FOR BELTS.

To find the speed of the driving pulley, multiply the diameter in inches of the driven pulley, by the number of revolutions it makes per minute, and divide the product by the diameter in inches of the driving pulley.

To find the speed of the driven pulley, multiply the diameter in inches of the driving pulley, by the number of revolutions it makes per minute, and divide the product by the diameter in inches of the driven pulley.

To find the final speed of a train of pulleys, multiply the number of revolutions per minute of the first driving pulley, by the product of the diameters of the driving pulleys, and divide the result by the product of the diameters of the driven pulleys.

To find the diameter of the driving pulley, multiply the diameter in inches of the driven pulley, by the number of revolutions it makes per minute, and divide the product by the number of revolutions of the driving pulley.

To find the diameter of the driven pulley, multiply the diameter in inches of the driving pulley by the number of revolutions it makes per minute, and divide the product by the number of revolutions of the driven pulley.

To find the diameters of two pulleys, when the speeds of the driving and driven shafts are given: divide the speed of the driven shaft by the speed of the driving shaft, which will give the ratio of their speeds, and the diameters of the pulleys must be in the same ratio.

PROPORTIONS OF CAST-IRON PULLEYS FOR BELTS.

Proportions of Pulleys.—The arms of pulleys are mostly made straight, as shown in Fig. 127. When they are made according to the proportions in Table 30, they will not break from contraction in casting. The diameter of boss varies with the diameter of the pulley as well as with the diameter of shaft; the proper size is given in the following table.

Split-pulleys are convenient, as they are readily fixed and require no keys. The section of theboss of a split-pulley, is shown in fig. 128.

Number and Shape of Arms.—Pulleys up to 17 inches diameter should have 4 arms; and from 18 inches to 8 feet, 6 arms; and above that size, 8 arms. The section of the arm should be of oval shape, struck from a radius equal to ¾ the width of arm, and the edges should be rounded off instead of left sharp, as shown in Fig. 130.

Round Face of Pulleys.—When a belt is to work constantly in one position on the face of a pulley, the face should be rounded to the extent of ⅜ inch per foot of the width of the rim. But when the belt is to be shifted along the face of the pulley to drive fast and loose pulleys, the face should be turned flat.

The Width of Face of a pulley should be about one-fourth more than the width of the belt it has to carry.

Pulleys with Curved Arms.—Fig. 129 shows the way to project the curved arm of a pulley. Draw the horizontal centre-line, A B, and from it. with a radius of ¼th the diameter of the pulley, draw the centre-line of the arm for the bottom curve. From the point where the said radius is struck, draw a vertical line, and on that line, with a radius of ⅙th the diameter of the pulley, draw the centre-line of the arm for the top curve. The dimensions of the arm can be taken from Table 30.

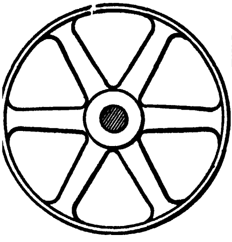
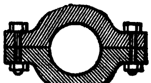
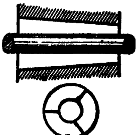


Fig. 127.—Pulley.

Fig. 128.





Figs. 131 and 132. --Cone-Keys.

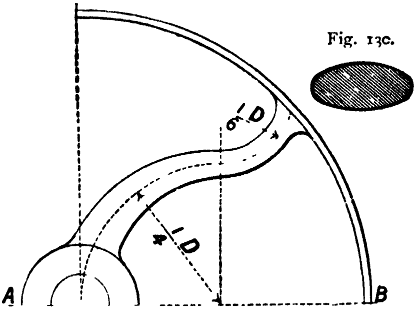
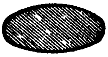


Fig. 129.—Pulley with Curved Arms.

Fig. 130.



Friction Cone-Keys, for fixing pulleys on shafting, are used for pulleys not made in halves, which require to be passed over swells on shafting. They are also fitted to split pulleys in cases where they have to fit different sizes of shafts. A cast-iron cone is turned to a taper of ⅜ inch in diameter per foot in length, and the pulley is bored to suit it. The cone is split after being turned, into three pieces. The minimum thickness of metal at the small end of the cone, should be ⅝ inch. See Figs. 131 and 132.

Strain on Bearings due to Pulleys and Pull of Belts.—The gross weight of shafting per foot in length, including the weight of the pulleys, and the load due to the pull of the belts, is equal to about two and one-half times the weight per foot in length of the shafting.

Table 30.—PROPORTION OF THE ARMS AND BOSS OF CAST-IRON PULLEYS FOR BELTS.

Diameter of Pulley, in Inches.	DIMENSIONS OF ARMS.				Depth of Rib round Boss.	DIAMETER OF SHAFT, 1½ TO 2 INCHES.	DIAMETER OF SHAFT, 2⅛ TO 3 INCHES.	DIAMETER OF SHAFT, 3⅛ TO 4 INCHES.	DIAMETER OF SHAFT. 4⅛ TO 5 INCHES.	DIAMETER OF SHAFT, 5⅛ TO 6 INCHES.
	Width at Boss.	Thickness at Boss.	Width at Rim.	Thickness at Rim.		Thickness of Metal round Shaft.	Thickness of Metal round Shaft.	Thickness of Metal round Shaft.	Thickness of Metal round Shaft.	Thickness of Metal round Shaft.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
12	1¾	¾	1¼	⅝	⅞	1	1⅛	1¼	1⅜	1½
15	1⅞	¾	1⅜	⅝	1	1	1⅛	1¼	1⅜	1½
18	2	¾	1½	⅝	1	1	1⅛	1¼	1⅜	1½
21	2⅛	⅞	1⅝	¾	1⅛	1⅛	1¼	1⅜	1½	1⅝
24	2¼	⅞	1¾	¾	1⅛	1⅛	1¼	1⅜	1½	1⅝
27	2½	1	2	⅞	1¼	1⅛	1¼	1⅜	1⅝	1¾
30	2¾	1	2⅛	⅞	1¼	1⅛	1¼	1⅜	1⅝	1¾
33	2⅞	1	2¼	⅞	1⅜	1¼	1⅜	1½	1⅝	1¾
36	3	1⅛	2⅜	1	1½	1¼	1⅜	1½	1¾	1⅞
39	3⅛	1⅛	2⅜	1	1½	1¼	1⅜	1½	1¾	1⅞
42	3¼	1⅛	2½	1	1⅝	1⅜	1½	1⅝	1¾	2
45	3⅜	1⅛	2⅝	1	1¾	1⅜	1½	1⅝	1¾	2
48	3½	1¼	2¾	1⅛	1¾	1½	1⅝	1¾	1⅞	2⅛
54	3⅝	1¼	2⅞	1⅛	1¾	1½	1⅝	1¾	1⅞	2⅛
60	3¾	1¼	3	1⅛	1⅞	1⅝	1¾	1⅞	2	2¼
66	4	1⅜	3⅛	1⅛	2		1¾	1⅞	2	2⅜
72	4¼	1⅜	3¼	1⅛	2¼		1⅞	2	2¼	2½
84	4½	1½	3½	1¼	2¼		2	2¼	2½	2¾
96	5	1⅝	3¾	1¼	2½		2¼	2½	2¾	3

Table 31.—Weight of Cast-Iron Pulley Castings, both Whole and Split, that is in Halves, bolted together.

Diameter of Pulley.	Width of Face.	Weight.						Diameter of Pulley.	Width of Face.	Weight.					
		Whole.			Split.					Whole.			Split.		
Inches.	Inches.	cwt.	qr.	lb.	cwt.	qr.	lb.	Inches.	Inches.	cwt.	qr.	lb.	cwt.	qr.	lb.
6	3	0	0	10	0	0	14	33	8	1	2	24	2	0	18
8	3	0	0	12	0	0	16	33	12	2	0	20	2	2	14
9	3	0	0	14	0	0	18	34	8	1	3	15	2	1	9
10	3	0	0	17	0	0	22	34	12	2	1	10	2	3	4
10	6	0	1	0	0	1	8	35	8	2	0	4	2	2	0
11	3	0	0	18	0	0	27	35	12	2	1	15	2	3	10
11	6	0	1	7	0	1	17	36	6	1	1	10	1	3	5
12	3	0	0	20	0	1	2	36	8	1	2	8	2	0	14
12	6	0	1	10	0	1	20	36	12	2	2	0	2	3	24
13	3	0	0	22	0	1	4	37	6	1	1	22	1	3	20
13	6	0	1	12	0	1	23	37	8	1	3	0	2	2	18
14	3	0	0	25	0	1	8	37	12	2	3	6	3	1	7
14	6	0	1	20	0	2	3	38	6	1	2	4	2	0	3
15	3	0	1	0	0	1	12	38	8	2	0	0	2	2	0
15	6	0	1	24	0	2	9	38	12	3	0	0	3	2	0
16	3	0	0	27	0	1	12	40	6	1	2	16	2	0	21
16	6	0	2	0	0	2	14	40	8	2	0	20	2	3	13
17	3	0	1	3	0	1	18	40	12	3	0	20	3	2	25
17	6	0	2	3	0	2	18	42	6	1	3	0	2	1	8
18	3	0	1	6	0	1	22	42	9	2	2	5	3	0	14
18	6	0	2	6	0	2	22	42	12	3	1	12	3	3	12
19	3	0	1	8	0	2	0	45	6	2	0	0	2	2	16
19	6	0	2	10	0	3	2	45	9	2	1	5	2	3	21
20	3	0	1	12	0	2	12	45	12	3	2	4	4	1	20
20	6	0	2	14	0	3	12	48	6	2	1	4	2	3	23
21	4	0	1	22	0	2	21	48	9	2	3	14	3	2	6
21	6	0	2	14	0	3	13	48	12	3	2	8	4	0	0
22	4	0	1	25	0	2	27	54	6	2	2	16	3	1	16
22	8	0	3	14	1	0	10	54	9	3	0	4	3	3	4
24	4	0	2	0	0	2	26	54	12	4	3	10	5	2	10
24	8	1	0	0	1	0	26	57	6	2	3	0	3	1	26
24	12	1	1	18	1	2	16	57	9	4	0	21	4	3	19
25	4	0	2	3	0	3	0	57	12	5	1	13	6	1	10
25	10	1	0	12	1	1	10	60	7	3	0	18	3	3	20
26	6	0	2	24	0	3	23	60	9	4	2	5	5	1	2
26	12	1	2	3	1	3	2	60	12	5	3	18	6	2	14
27	4	0	2	10	0	3	8	66	8	4	1	12	5	0	13
27	8	1	0	10	1	1	8	66	12	6	2	5	7	1	4
27	12	1	2	9	1	3	8	66	14	7	2	13	8	1	15
28	4	0	2	16	0	3	15	72	8	5	0	0	5	3	2
28	8	1	1	4	1	2	26	72	12	7	1	16	8	0	18
28	12	1	3	0	2	0	0	72	14	8	2	12	9	1	14
29	6	0	3	22	1	0	24	75	8	5	2	23	6	2	0
29	8	1	1	24	1	2	26	75	12	8	0	0	8	3	6
29	12	1	3	10	2	0	12	75	14	9	1	0	10	0	4
30	6	1	0	0	1	1	4	78	9	6	2	10	7	2	0
30	8	1	2	3	1	3	7	78	12	8	3	0	9	2	14
30	12	1	3	20	2	0	25	78	14	10	0	0	11	0	8
31	6	1	0	10	1	1	20	84	9	8	0	3	9	0	10
31	8	1	2	14	1	3	26	84	12	10	2	17	11	3	0
31	12	2	0	4	2	1	14	84	14	12	2	0	13	2	8
32	6	1	0	16	1	2	0	90	10	10	0	6	11	1	0
32	8	1	2	16	2	0	0	90	14	14	0	0	15	0	18
32	12	2	0	10	2	1	21	96	12	13	1	0	14	2	10
33	6	1	0	23	1	2	16	96	15	16	2	0	17	3	20

Belt-Pulleys or Riggers.—The preceding table gives the weight of pulley castings, cast from a good set of patterns. The rims of main driving pulleys, may be strengthened without materially increasing the weight, by casting a rib about $\frac{5}{8}$ inch square, round the edge of the inside of the rim, like Fig. 133.

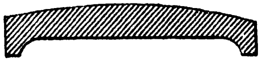


Fig. 133.—Section of Rim of Pulley.

The weight of turned pulleys, may be found by deducting 12 lbs. for every cwt. in weight of the casting, which is the average reduction in weight due to turning and boring the same.

Pulleys of Wrought-Iron, Steel and Wood.—Pulleys of wrought-iron are generally about 40 per cent. lighter, of steel 45 per cent. lighter, and of wood 70 per cent. lighter, than cast-iron pulleys. Some wood pulleys are, however, about 40 per cent. lighter than wrought-iron pulleys, and they transmit about 50 per cent. more, and leather-covered pulleys 20 per cent. more, power than cast-iron pulleys.

Belt-Driving.—The motion transmitted by a belt, is maintained solely by the frictional adhesion of the belt to the surface of the pulleys. Belts will not communicate motion with precision, on account of their liability to slip on the pulleys. When one pulley is larger than the other, an open belt will slip on the smallest one first, because the arc of contact is smaller; but if the belt be crossed, the arc of contact will be the same, whatever the diameter of the pulleys may be. A belt will always climb to the highest point of a pulley, and the position it takes upon a driven pulley is determined by the side of the belt which moves towards the pulley.

A long horizontal belt increases the tension and arc of contact, by its own weight forming a curve between the pulleys, therefore it should drive from the under side, then the slack side is on the top and drops between the pulleys. A belt running on a pulley on a vertical shaft requires to be stretched very tightly over the pulleys, because its weight lessens its contact, and it should therefore be made broader than a horizontal belt.

The working tension of leather belts should not exceed 330 lbs. per square inch of the section of the belt. The adhesive grip of a belt, is the same on cast-iron pulleys whether they are turned or not, but it is greater on a wooden than on a cast-iron pulley.

The strain in lbs. upon the driving side of a belt, due to the power transmitted, independent of the initial tension producing adhesion between the pulley and the belt, is found thus: Multiply the number of the horse-power by 33,000, and divide the product by the velocity of the pulley in feet per minute. The velocity is found by multiplying the circumference of the pulley in feet by the number of revolutions per minute.

The Actual Horse-power of a Belt is found thus. Multiply the force in lbs. transmitted to the surface of the pulley, by its velocity in feet per minute, and divide the result by 33,000.

The Horse-power transmitted by Single Leather Belts is found thus: Multiply the diameter of the pulley in inches, by the width of belt in inches, and multiply the product by the number of revolutions per minute, then divide by the constant number due to the arc of contact of the belt, which is given in the following table.

To find the Width of a Single Leather Belt.—Multiply the nominal horse-power, by the constant number due to the arc of contact of the belt, and divide by the product of the number of revolutions per minute, and the diameter of the pulley in inches.

Table 32.—MULTIPLIERS FOR THE ABOVE RULES FOR THE HORSE-POWER OF SINGLE LEATHER BELTS.

Portion of the circumference of the pulley in contact with the belt	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$
Constant multiplier or divisor for the above rules	5715	4737	4000	3590	3297

The arc of contact, of the smaller of two pulleys, must be taken in calculating belts, when an open one is employed, but when a cross belt is employed, the arc of contact will be the same for both pulleys, and the arc of contact, of either of them may be taken.

Double Belts.—A double leather belt will drive double the power of a single one, and consequently it only requires to be one-half the width of a single belt, to drive the same power.

Table 33.—WEIGHT IN LBS. OF 100 FEET IN LENGTH OF SINGLE AND DOUBLE LEATHER BELTING.

Width of Belt, Inches. .	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	11	12	14	16
Single Belt, Strong, lbs. .	14	19	25	31	38	43	50	54	67	78	100	110	130	140	160	200	—
Single Belt, Medium, lbs.	12	17	23	29	35	40	47	51	64	74	94	100	120	130	150	180	—
Double Belt, Strong, lbs. .	30	35	46	59	70	80	90	100	110	150	175	200	230	250	280	340	380
Double Belt, Medium, lbs.	24	30	40	53	64	74	84	93	103	142	165	190	220	250	270	325	360

The safe working tension of Leather Belting is 20 lbs. per inch in width, for each one-sixteenth of an inch in thickness of the belt, or 40 lbs. per inch in width, for each one-eighth of an inch in thickness.

The Breaking Strain per square inch of section, of best quality leather belting is . . . . 3,360 lbs.

The breaking strain, per square inch of section, of best quality stout stitched cotton belting is . . . . 6,800 lbs.

The breaking strain, per square inch of section, of best quality stout solid-woven cotton belting is . . . . . . 10,420 lbs.

The belts for use in wet or damp places are:—	lbs.
Waterproof Linen Belting—4 ply—Breaking strength per square in.	12.000
India-rubber Belting—4 ply, $\frac{5}{16}$ inch thick, with canvas layers—Breaking Strain per square inch	1,020

The strengths of belting only refer to new belts of best quality.

The Co-efficients of Friction for Belts and Ropes, based on experiments, are as follows:

For new belts on wooden pulleys	·50
For leather belts in ordinary condition on wooden pulleys . . .	·47
For belts in ordinary condition on cast-iron pulleys, either turned or not	·28
For wet belts on cast-iron pulleys	·38
For hemp ropes on wooden pulleys	·50

A rope when wound round a Barrel with a rough surface, offers very great frictional resistance to sliding, the resistance being the following number of times greater than the pull at the slack end: viz.—

24 when the rope is wound once round the barrel.
111 when the rope is wound $1\frac{1}{2}$ times round the barrel.
535 " " 2 " "
2575 " " $2\frac{1}{2}$ " "

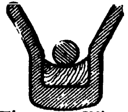


Fig. 134.- Wire-Rope Pulley.

Transmission of Power to Long Distances.—Power may be efficiently transmitted to long distances by a system of flexible wire ropes and pulleys. The wire-ropes are from $\frac{3}{8}$ to 1 inch diameter, and consist of a number of strands of iron wire, wound round a core of hemp, each strand consisting of 6 or more fine wires wound round a core of hemp. The wire rope runs at a speed of about 60 feet per second, on grooved pulleys of from 12 to 15 feet diameter; the bottom of the groove is round in shape and is composed of willow wood, sunk into the casting of the pulley. The distance between the pulleys should not be less than 70 yards,—because short wire ropes do not run steadily in working—and it may be any reasonably greater distance, guide pulleys—spaced about 70 yards apart—being used to support the rope in long distances. The rope rests upon the bottom of the groove, clear of the sides; the following are good proportions for the groove, viz.: Depth of groove from where the rope rests to the top of the rim of the pulley = $2\frac{1}{2}$ times the diameter of the rope: Width of groove at the top = 4 times the diameter of the rope: Radius of the bottom of the groove on which the rope rests = the diameter of the rope: Thickness of wood at the bottom of the groove = the diameter of the rope: Weight of the rope in lbs. per yard, in length = four times the square of the diameter of the wire-rope, in inches. For Section of Rim, see Fig. 134.

Horse-power of Wire-rope Gearing.—To find the number of indicated horse-power transmitted by wire-rope gearing. *Rule:* Multiply the strain in lbs. at the circumference of the pulley, by the velocity of the rope in feet per second, and divide the product by 550. The strain in lbs at the circumference of the pulley is equal to 550 times the horse power divided by the velocity of the rope, in feet per second.

SECTION IV

STEAM BOILERS, SAFETY VALVES, FACTORY CHIMNEYS, &c.

SECTION IV.

STEAM BOILERS, SAFETY VALVES, FACTORY CHIMNEYS, &c.

STEAM BOILERS.

Effect of Heat upon Water.—When heat is first applied under a boiler, the material of the boiler absorbs and transfers the heat to the water, which causes the water to circulate. The water at the bottom becomes heated first and expands, and being lighter than the rest, is forced upwards by the greater density of the colder water above it, and a current of colder water descends and takes its place, and in turn becomes heated; afterwards the particles of water expand, and form themselves into bubbles of steam (that is, the heat becomes enclosed in films of water), and gradually ascend until they are robbed of their heat by the colder water, which they come in contact with in their ascent; then they condense and disappear. When the water becomes uniformly heated, the bubbles increase in size and number, and ascend higher as the heat increases, until the temperature of the whole reaches 212° Fahr., when the water will boil, and all subsequent additions of heat, will be carried off by the water in the form of steam. This is called convection, and is the only way water can be heated, as, being a bad conductor of heat, water cannot be heated by conduction.

Fresh water boils under atmospheric pressure at 212° F., and one cubic inch produces about one cubic foot of steam, equal in pressure to that of the atmosphere, or 14·7 lbs. per square inch, and until this point is reached steam will not rush into the atmosphere; therefore, unless the pressure of the atmosphere is removed, only pressures above 15 lbs. are available for performing work. The boiling point is always constant for the same liquid under the same conditions; but foreign substances, held in solution with it, considerably affect it. The boiling point rises in a closed vessel, as the pressure of the steam increases, because the tension of the vapour has to overcome a greater pressure, before it can escape from the water; but the temperature of steam is always the same as the water, which produced and is in contact with it, and there is a fixed temperature and density, to each pressure of steam when in contact with water.

The Expansive Force of Steam is nearly inversely as the volume; thus, if steam at 15 lbs. pressure occupies one cubic foot, the same quantity at 30 lbs. pressure would only occupy about half a cubic foot. Steam contains about 5½ times as much heat as water; at atmospheric pressure, steam is 1,700 times the volume of the water which produced it.

The Elastic or Mechanical Force of Steam increases in a much greater ratio than its temperature; thus, at 212° its force is, in round numbers, 15 lbs. per square inch, but if its temperature be raised to 283° the force is 52 lbs. As small additions of heat produce a rapid increase of force, so small abstractions of heat rapidly reduce the elastic force.

Saturated Steam.—When steam is in contact with the water from which it was generated, it is called saturated steam.

Superheated Steam.—Under normal conditions a boiler unprovided with a superheater supplies steam together with varying quantities of moisture. When the steam is isolated from the water which produces it and further heat is supplied it is termed superheating, or the addition of heat to dry saturated steam without an increase in pressure. In order to obtain the greatest economy from superheating it is necessary for the prime move to be specially designed. The saving in fuel consumption from the use of superheated steam will vary according to the amount of saturated steam that would be required per h.p. With 100° to 150° of superheat it would be reasonable to expect a reduction in steam consumption of about 20 per cent. with a single cylinder non-condensing engine, and from 10 to 20 per cent. with a compound condensing engine. The saving in fuel consumption from the use of superheated steam in turbines would be approximately 8 per cent.

Combustion of Coal and the Evaporative Power of Fuels.—The total heat per lb. of coal may be expressed in units of evaporation, a unit of evaporation being the quantity of heat required to convert 1 lb. of water of 212° into steam at the same temperature; or in units of heat, a unit of heat being the quantity required to raise the temperature of 1 lb. of water 1°. Coal is composed of carbon,—1 lb. of which yields 14,500 units of heat, and of hydrogen,— 1 lb. of which yields 62,032 units of heat, and of sulphur,—1 lb. of which yields 4,032 units of heat. From the results of ultimate analyses on 98 samples of coal, the average composition was deduced as follows:

Carbon	·80	or 80	per cent.	Sulphur	·0125	or 1¼	per cent.
Hydrogen	·05	or 5	„	Oxygen	·08	or 8	„
Nitrogen	·012	or 1⅕	„	Ash	·04	or 4	„

From this we find that the total heat of combustion of coal is:—

	Units of heat.
Carbon, 14,500, multiplied by ·80 =	11,600
Hydrogen, 62,032, multiplied by $\left(\cdot 05 - \frac{\cdot 08}{8}\right)$* =	2,481
Sulphur, 4,032, multiplied by ·0125 =	50
Total	14,131

---

* A portion of the hydrogen combines with the oxygen and forms water, and a deduction from the hydrogen of a quantity equal to ⅛ of the oxygen must be made to provide for this condition.

By dividing this quantity by the units of heat required to convert 1 lb. of water of 212° into steam of the same temperature (14,131 ÷ 966), we have 14·63 units of evaporation, or 14·63 lbs. evaporated from and at 212°.

Coke contains ·86 carbon, but no hydrogen or oxygen, and yields (14,500 multiplied by ·86) = 12,470 units of heat.

Wood, when dry, contains ·50 carbon, and the hydrogen and oxygen combine without yielding heat; and yields (14,500 multiplied by ·50) = 7,250 units of heat per lb.

Peat contains about one-third more units of heat than wood. The above figures are the maximum heating powers from which a deduction must be made for imperfect combustion. In practice it is impossible to utilize all the available heat, and it is distributed approximately as follows :

Heat lost by radiation—10 per cent.
Heat lost by ashes falling unburnt through the fire bars— 5 per cent.
Heat lost by gases escaping at a high temperature to the chimney—20 per cent.
Heat used in producing steam in internally fired boilers—65 per cent.

The average evaporative power, of different kinds of fuels, is as follows :—

1 lb. good coal will evaporate 9 lbs. water which	has been	raised to 212°.
$\frac{5}{8}$ lb. of petroleum—Ditto.	ditto.	ditto.
2 lb. of dry peat—Ditto.	ditto.	ditto.
$2\frac{1}{2}$ lbs. of dry wood—Ditto.	ditto.	ditto.
$3\frac{1}{4}$ lbs. of cotton stalks—Ditto.	ditto.	ditto.
$3\frac{1}{2}$ lbs. of brushwood—Ditto.	ditto.	ditto.
$3\frac{8}{4}$ lbs. of wheat or barley straw—Ditto.	ditto.	ditto.
4 lbs. of megass or sugar cane refuse—Ditto.	ditto.	ditto.

Liquid-Fuels comprise all classes of fluid hydrocarbons, such as, the mineral hydrocarbons of bitumen and asphalt; oils obtained by destructive distillation of coal, shale and schist; and animal and vegetable fats and oils. The heating-effect of liquid-fuel, when injected into the furnace in the form of spray, is about 3 times as great as that of coal.

The consumption of coal per indicated horse-power per hour, in first-class triple-expansion surface-condensing engines, is about $1\frac{1}{2}$ lbs., in double-expansion condensing engines, from $1\frac{3}{4}$ to 2 lbs.; in single cylinder condensing engines, $2\frac{1}{2}$ to 3 lbs.; in locomotives, $2\frac{1}{2}$ lbs.; and in high pressure non-condensing simple engines, 3 to 4 lbs.

CYLINDRICAL STEAM-BOILERS.

Boiler-Shells.—The resistance of a boiler shell to internal pressure, varies inversely as the diameter. A shell 2 feet diameter, will bear double the internal pressure of one 4 feet diameter, the thickness being the same in both cases. The resistance of the plates varies as their thickness. A shell of ½ inch thickness, will bear double the pressure of one ¼ inch thickness, the diameter of the shell being the same in both cases. The thickness of the plates should be in proportion to the diameter of shell. A shell of 6 feet diameter, will require plates double the thickness of one 3 feet diameter, to resist the same pressure. The pressure of steam being equal in all directions, the pressure inside the shell of a boiler, acts uniformly all round its circumference, and tends to maintain its form perfectly circular, and also to restore any departure of its shape from a true circle. The shell cannot, however, be made perfectly circular, owing to the plates overlapping each other at the longitudinal seams, but the amount of deviation caused thereby, is so small that it need not be taken into consideration. The circumferential strain, being the greatest from the pressure inside the shell, the plates should be placed lengthways round the circumference, that is, the fibre of the iron should run round the circumference, because the plates are strongest in the direction in which they were rolled. The longitudinal seams should not be in line from end to end, but they should break joint, thereby considerably increasing the strength of the shell, and the longitudinal seams should be placed away from the centre line, along the top and bottom of the boiler. The transverse joints, requiring only half the strength of the longitudinal seams, only require to be single-riveted ; but the longitudinal seams should be double-riveted.

Longitudinal Strain on Boiler-Shells.—The strain inside a boiler-shell, tending to rupture it longitudinaily in lines parallel to its axis, is found by multiplying the diameter in inches by the length in inches, and then by the pressure of steam per square inch.

Transverse Strain on Boiler-Shells.—The strain inside a boiler-shell, tending to rupture it transversely in lines at right angles to its axis, is the amount of pressure against each end of the shell, and it is found by multiplying the area of the end of the shell in square inches, by the pressure per square inch.

Length of Boilers.—The strength of a boiler is not affected by its length as regards internal pressure, but the liability to strain increases with the length; short boilers do more work in proportion than long ones. The minimum length of Cornish and Lancashire boilers, for confined positions, should be 2½ times the diameter, and the maximum, and best working length, should be 4 times the diameter.

Cornish and Lancashire Boilers are more frequently used for land purposes than any other form of boiler, and cannot be surpassed for accessibility, simplicity and durability. They are steady and good steam producers, they will burn the commonest qualities of fuel, and with a good draught they will burn any kind of refuse fuel. Although the thermal efficiency of such boilers without economisers or air heaters, is invariably lower than the average obtainable with other equally reliable types, they continue to be preferred for units of less than 12,000 lbs. per low evaporation.

Cornish Boilers.—Cornish or single flue-tube boilers, are made from 3 to 5 feet in diameter. The flue-tube is generally made one-half the diameter of the shell, and is fixed so as to leave a depth of 6 inches, between the bottom of the flue-tube, and the bottom of the shell, which is ample space for the proper circulation of the water, and leaves sufficient depth of end plate, to allow it to yield to the expansion and contraction of the flue-tube. When less depth of water-space than this is allowed, the bottom part of the end plate is liable to crack, for want of sufficient flexibility, to allow for its springing during unequal expansion, owing to the top portion of the flue-tube becoming much hotter, and expanding more than the bottom portion, which causes the end plates to be forced out at an angle; to provide for this unequal expansion, the end plates should be made as flexible as possible.

Lancashire and Cornish Boilers.—British Standard Specification number, 537—1934, published by The British Standards Institute, 28, Victoria Street, London, S.W.1, 3s. 6d. net, applies to the above boilers, exclusive of brickwork, settings, insulation and mountings.

End Plates of Cornish and Lancashire Boilers.—The back end plate may be attached to the shell by an inside angle-hoop, but in order to increase the flexibility of the front end plate, it should be attached to the shell by an outside angle-hoop. The end plate should be made out of one piece of plate, and the openings for flues should be cut out in a lathe.

Gusset-Stays.—The end plates of Lancashire and Cornish boilers should be stayed to the shell by gusset-stays, of single plates and double angle-steel. The number of stays will depend upon the size of boiler; large boilers should have 5 at each end above the flue tubes: 2 at the front end, and one at the back end below the flues; two of the gusset-stays should be secured to the second belt of plates of the shell, and the bottom of the gusset-stays should not go nearer to the flue than 10 inches from the bottom rivet in the stay to the rivets of the angle-hoop connecting the flue-tube to the shell, so as not to injure the flexibility of the end plate.

Longitudinal Stay-Bolts.—The end plate of Lancashire and Cornish boilers, should be stayed with two longitudinal stay-bolts, one on each side of the centre gusset-stay, at a good height above the flue, so as not to injure the flexibility of the end plates. The screwed part of the stay-ends, should be larger in diameter, than the body of the stay, so that the diameter at the bottom of the thread, may not be less than the plain part of the stay. The stay should be secured to the end plates, by nuts and washers both inside and outside.

Internal Flue-Tube.—As the pressure acts all round the circumference of a flue-tube, in order to make the pressure uniform the flue should be a true circle; any deviation therefrom, seriously weakens it, and the external pressure tends to increase the amount of deviation from the true circle, and to collapse the flue. When the plates overlap each other in the longitudinal seams, the flue cannot be made perfectly circular, and the amount of deviation caused thereby, reduces its strength to resist external pressure, to the extent of 30 per cent.

Longitudinal Seams of Internal Flue-Tubes.—The longitudinal seams of furnaces are usually welded, otherwise it would be necessary they should be made with butt joints double riveted, with the strip on the outside of the flue.

Diameter of Flue-Tube.—The resistance of internal flues to collapse, varies inversely as the diameter, a tube 12 inches diameter, being double the strength of one 24 inches diameter, and as wrought-iron will sustain double the force to tear it asunder, that it will to crush it, the diameter of the internal flue should never exceed one-half the diameter of the boiler.

Length of Flue-Tube.—The resistance of wrought-iron flues to collapse, varies inversely as the length, a tube 5 feet long being double the strength of one 10 feet long; but as flues are constructed with several belts of plates, the ring seams add considerable strength to the flues, and by strengthening the ring seams the length is practically reduced to the distance between each ring seam; the best mode of strengthening the ring seams is the Adamson flanged seam.

Longitudinal Expansion of Flue-Tube.—The flue expands more longitudinally than the shell, and unless provision is made for this expansion, the tube in expanding will become arched, and likewise will cause the end plates to spring out. This can be prevented by making the ring seams of the flue with Adamson's flanged joint, shewn at Fig. 142, which will allow the flue to expand sufficiently, and the strain on the end plates will be reduced.

Corrugated Furnaces.—The proportions of corrugated flue sections are made in accordance with British Standard Specification number 3023, and the minimum finished thickness is determined by the following formula:

$$t = 1 + \frac{WP \times D}{C}$$

where D = the least external diameter in inches.

t = the minimum finished thickness of the plate in thirty-seconds of an inch.

WP = working pressure in lbs. per square inch.

C = 480 for Fox, Morrison and Deighton corrugations.

= 510 for Leeds Forge Bulb corrugations.

Man-hole.—The man-hole of Cornish and Lancashire boilers should be guarded with a strong wrought-iron raised mouth-piece, welded into one piece, flanged at the bottom, and riveted to the boiler with a double row of rivets,—the diameter inside should be 16 inches, the height 8 inches, the thickness of the body should be equal to double the thickness of the shell of the boiler, and the flanges should be one-fourth thicker than the body. Cast-iron should never be used for this purpose, because it elongates much less with the same stress than wrought-iron, and as they both must stretch together, the cast-iron will give way long before the breaking strain comes on the wrought-iron. When a raised mouth-piece is not used, a strengthening-ring equal in thickness to not less than $1\frac{3}{4}$ the thickness of the shell, and in width to 12 times the thickness of the shell, should be riveted on with rivets, at centres equal to 4 times the diameter of the rivets.

Mud-holes.—The mud-hole at the front of the boiler, beneath the furnace-tubes of Lancashire boilers, should be guarded with a strong wrought-iron mouth-piece, and the small mud-holes of vertical and other boilers, should be guarded with a strong mouth-piece, raised sufficiently to form a flat face for the cover to bed against.

Boiler Fittings for Cornish and Lancashire Boilers.—Every boiler should have two safety-valves, and two water-gauges: the one acts as a check on the other. The water-gauges should be fixed, so that the lowest visible point of the glass, is 5 inches above the highest point of the internal flue; the average working height of water above flues is from 9 to 10 inches. Height of deadplate above floor 2 feet 8 inches. Inclination of boiler towards blow-off cock, $\frac{1}{2}$ inch in 10 feet. Inclination of fire-bars towards back of boiler, 1 inch in 12 inches. The height of the bridge at the back of the fire-grate, should be made such, as to leave a passage over it, equal to one-sixth of the area of fire-grate. The mouth-piece of the furnace should be made of two wrought-iron plates, with an air-space between, the door of which should have a sliding grid on the outside and a perforated box baffleplate on the inside, for admitting air above the fire. The size of the perforations should not exceed $\frac{3}{8}$ inch in diameter, and the sum of their areas should not be less than 3 inches per square foot of fire-grate surface.

Boiler Setting.—Cornish and Lancashire boilers, should rest upon fire-brick seating blocks, set on side walls. These seating blocks are made with a convex edge so that the boiler will rest upon a very narrow surface, and the minimum of metal will be covered. Each side flue should be 12 inches wide, carried up to the level of the furnace crown, and down to the level of the bottom of the boiler, the width of the bottom flue under the boiler should be equal to one-half the diameter of the boiler, and the depth of the flue should be about 2 feet 6 inches. When thus set, the flame after leaving the furnace-tube, passes under the bottom of the boiler, and returns to the chimney along the side flues. The face of the brick-work, at the front of the boiler, should be set back 6 inches, so as to leave the angle-iron and its rivets open. Fire-clay, instead of lime, should be used throughout, in setting the boiler.

Staying Flat Surfaces.—In a flat surface, such as the side of a locomotive firebox, each stay sustains the pressure on the square area of plate which surrounds it, whose side is equal to the distance between the centres of the stays; and the strain on the flat surface between the stays, is found, by multiplying the area in square inches between the adjacent stay-rods by the pressure.

The diameter of staybolts, for flat surfaces, should not be less than twice the thickness of the plate, and should never exceed three times the thickness of plate.

The working steam pressure of staybolts, per square inch of section at the threads, should not exceed 4,300 lbs., to provide against wasting from corrosion.

The distance of centres of staybolts is found thus: Multiply the constant number, 4,300, by the area of the staybolt, and divide the product by the working pressure; then take the square root of the quotient, and the answer will be the proper centres. The usual pitch for locomotive fire-box stays is 4 inches centres, irrespective of the thickness of plate.

The dished end of a cylindrical shell, such as the top of a dome, should be dished to a radius equal to the diameter of the cylinder, in order to make it equal in strength to the cylinder, a hollow sphere being twice as strong as a cylindrical shell, of the same radius and thickness.

Position of Feed Delivery in Boilers.—In Cornish and Lancashire boilers, the feed should be introduced on one side of the front end plate, about 4 inches above the furnace crown, through an internal dispersing pipe, carried inside the boiler to at least one-third of its length, and perforated for the last half of the pipe's length; and in vertical boilers, the feed should be introduced through a short perforated pipe, so as to deliver just below the water-level, but clear of the fire-box and tubes. When the feed is introduced below the furnace crown, if anything gets into the back-pressure valve to prevent its closing, the pressure in the boiler will force the water back through the feedpipe, and the furnace crown will become bare and overheated.

Heating Feedwater.—In order to prevent unequal expansion and contraction, by keeping an even temperature in the boiler, and also to save fuel, the feedwater should always be heated. In heating by exhaust steam, the feedwater should not be allowed to come in direct contact with the exhaust steam, but the steam should pass through pipes around which the feedwater should be made to pass. One great advantage of a feedwater heater, is, that it arrests the substances held in suspension by the water, and scale, &c., is deposited in the heater, which would otherwise form in the boiler. The exhaust steam from a non-condensing engine, will heat the feedwater to within a few degrees of the boiling point (212°), and a saving of about 13 per cent. will be effected over cold water.

In condensing engines the feedwater is generally taken from the hot well, at about 100°, effecting a saving of about 4½ per cent. over cold water.

Evaporative Power of Boilers.—The factors governing the evaporative power of any boiler are:

Area of fire-grate or furnace.

Air supply to furnaces.

Accessories such as economisers and air-heaters.

Class and quality of fuel being consumed.

Thermal efficiency.

Nominal Horse-power of Boilers.—This term is not used in connection with Lancashire, Cornish or water-tube boilers, but is still used to indicate the power of the smaller sizes of vertical boilers.

Nominal horse-power of vertical cross tube boilers: Add together the diameter of the shell, the diameter of the fire box, the diameters of all the tubes, and the diameter of the uptake tube, all in feet; multiply the sum by the length in feet, and divide by 10.

Nominal horse-power of vertical tubular boilers, with vertical tubes: Add together the diameter of the shell, the diameter of the fire box, the diameters of all the tubes, all in feet; multiply the sum by the length in feet and divide by 12.

The equivalent horse-power of a boiler may be estimated by dividing the weight of water evaporated to steam per hour, by the weight of steam consumed per indicated horse-power of the engine per hour.

Evaporative Test of a Boiler.—The simplest way of ascertaining the approximate actual evaporation of any boiler is as follows. When the boiler is working satisfactorily, feed the boiler up to the top of the water-gauge glass, then shut off the feed, weigh all the coal used after this time, and observe the time occupied in reducing the water from the top to the bottom of the glass; fire carefully, and see that the same quantity of fire is left at the end as at the beginning of the test. Then the evaporative power may be ascertained, from the data obtained in the test, by the following rules:—

To find the number of cubic feet of water evaporated per hour: Multiply the number of square feet of water-surface, by the evaporation in inches of gauge-glass, multiply the product by 5, and divide the result by the number of minutes occupied in evaporation.

To find the quantity of water in lbs. evaporated per lb. of coal: Multiply the number of cubic feet of water evaporated per hour, by 62·5 and divide the product by the quantity of coal in lbs. consumed per hour.

Heating Surface.—The evaporative power of a boiler depends upon the efficiency of its heating surface, the values of which are as follows:—

All horizontal surface above the flame .
$\frac{1}{2}$ vertical surface . . . . . .
$1\frac{1}{4}$ the diameter of tubes or round flues .
$1\frac{1}{6}$ convex surfaces above the flame . .
} Being taken as effective heating surface.

Horizontal surfaces beneath the flame, are of no value as heating surfaces.

Factor of Evaporation.—In order to simplify the performance of similar and different types of boilers, the effect of variation in feed-water temperatures and steam pressures are overcome by calculating an equivalent evaporation from and at 212° F. This can be obtained from $F = \frac{H-h}{970}$ where F is the factor of evaporation, H the total heat of steam and h the total heat of the feed water above 32° F.

Cornish and Lancashire Boilers *of 5 feet in diameter and upwards, should have the longitudinal seams of the plates either double-riveted or* treble-riveted according to the working pressure.

In fixing Galloway tubes, the welded part should face the back end of the boiler.

The Galloway Boiler is frequently installed in land installations and is an excellent steam producer—an 8 hours test of one with 70 lbs. pressure of steam, was conducted as follows: steam being raised to 70 lbs., the height of water in the boiler was noted, and the fires drawn: the fires were then re-lighted, all the fuel used was weighed, allowance being made for unconsumed fuel in the fires at the end of the test. Calorimeter observations were taken, a certain weight of steam being condensed in a given quantity of water, the dampness of the steam being determined by the increase of weight and temperature in the water, the feed-water was measured and also weighed. The boiler evaporated 11·72 lbs. of water at 212° F. per lb. of coal, or 2603 lbs. of water per hour, with a heating surface of 973 square feet.

Boiler Efficiency.—The percentage of heat gained by a steam generator may be expressed thus:

$$\frac{\text{Heat utilized by boiler}}{\text{Heat supplied to plant}} \times 100 = \text{efficiency per cent.}$$

To find the Number of Gallons of Water a Boiler will hold.—If a plain cylinder without tubes, multiply the square of the diameter in feet by the length in feet, and by 4·89; the answer will be in gallons. Or, multiply the square of the diameter in inches by the length in feet, and by ·034. Or multiply the square of the diameter in inches, by the length in inches, and by ·00283.

To find the Number of Gallons in a Cornish or Lancashire Boiler.—Multiply the sectional area of the boiler shell in inches, by the length of the shell in inches; multiply the combined sectional area of the flues in inches by their length in inches; subtract this product from the first, and divide the remainder by 1728; this will give the number of cubic feet of water the boiler will contain, which multiplied by 6·24 will give the contents in gallons of the boiler when full of water.

VERTICAL BOILERS.

The Firebox should be formed of plates of very ductile and superior quality. There should be one mudhole opposite the large end of each cross tube, and mudholes should be placed round the bottom of the boiler. The diameter of firebox given in the table is at the bottom; the top should be less in diameter; the taper should be about 1 inch per foot in height.

The Cross-Tubes should be lower at the small end than at the other, and their seams should be placed away from the fire.

Table 34.—PROPORTIONS OF CORNISH AND LANCASHIRE BOILERS.

	CORNISH BOILERS (ONE FLUE).									LANCASHIRE BOILERS (TWO FLUES).			
	ft. in.	ft in.	ft. in.	ft in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in
Diameter of shell . .	3 0	3 6	4 0	4 4	4 6	4 9	4 9	5 0	5 0	5 6	6 0	7 0	7 6
Length of shell . .	8 0	10 0	11 0	13 0	15 0	16 0	19 0	20 0	22 0	21 0	24 0	27 0	30 0
Thickness of shell .	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$
Diameter of flue .	1 6	1 9	2 0	2 2	2 3	2 4	2 5	2 6	2 6	Two. 2 0	Two. 2 3	Two. 2 9	Two. 3 0
Thickness of flue . .	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{7}{16}$
Thickness of ends .	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{5}{8}$
Length of fire-grate .	2 9	3 3	3 6	3 9	4 0	4 6	4 9	5 0	5 6	6 0	6 0	6 0	6 0
Number of Galloway tubes . . .					2	2	4	4	4	8	8	10	12
Approximate weight of boiler when of wrought-iron: in cwts. . . .	22	32	42	54	65	75	85	110	120	147	190	260	300
Approximate weight of boiler when of mild-steel: in cwts.	23	33	43	56	67	77	87	113	123	151	194	266	307

Table 35.—Proportions of Vertical Cross Tube Boilers.

Nominal Horse Power.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	14.	15.
	ft in	ft in.	ft. in	ft. in.	ft. in	ft. in	ft in	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
Diameter of shell .	2 6	2 7	2 9	3 0	3 3	3 6	3 6	3 9	4 0	4 6	4 6	5 0	5 0
Height of shell . .	5 0	5 6	6 0	7 0	7 6	8 6	9 0	9 0	9 0	9 0	10 0	10 0	11 0
Thickness of shell .	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$
Diameter of fire-box .	2 0	2 0	2 3	2 6	2 9	3 0	3 1	3 3	3 6	4 0	4 0	4 6	4 6
Height of fire-box .	3 3	3 6	3 9	4 0	4 6	5 0	5 3	5 6	5 9	6 0	6 3	6 6	7 0
Thickness of fire-box	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$
Number of cross tubes	1	2	2	2	3	3	4	4	4	4	4	5	5
Diameter of cross tubes . . .	6	7	8	8	8	8	8	8	9	9	9	9	9
Thickness of cross tubes . . .	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
Diameter of uptake .	6	7	8	8	8	9	9	10	10	1 0	1 0	1 0	1 0
Thickness of uptake .	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
Thickness of crowns .	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$
Approximate weight of boiler when of wrought-iron: in cwts. . . .	12	14	17	21	25	30	32	35	37	42	48	54	63
Approximate weight of boiler when of mild-steel: in cwts.	13	15	18	22	26	31	33	36	38	43	49	56	65

Table 36.—PROPORTIONS OF VERTICAL TUBULAR BOILERS WITH VERTICAL TUBES.

Nominal Horse Power	2.	3	4.	5.	6	7.	8.	9.	10.	11.	12.	14.
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
Diameter of shell . . .	2 6	2 7	2 9	3 0	3 3	3 6	3 6	3 9	4 0	4 6	4 6	5 0
Height of shell . . .	5 0	5 6	6 0	7 0	7 6	8 6	9 0	9 0	9 0	9 0	10 0	10 0
Thickness of shell . .	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$
Diameter of fire-box .	2 0	2 0	2 3	2 6	2 9	3 0	3 0	3 3	3 6	4 0	4 0	4 6
Height of fire-box . . .	2 6	3 0	3 2	3 4	3 6	3 9	4 0	4 0	4 0	4 0	4 6	4 6
Thickness of fire-box .	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$
Number of tubes . .	10	12	14	16	18	22	24	26	30	30	30	34
Diameter of tubes . . .	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{3}{4}$
Thickness of tube plate .	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$
Thickness of crown . .	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$
Approximate weight of boiler when of wrought-iron: in cwts. . . .	12	15	19	22	26	31	33	37	40	45	50	57
Approximate weight of boiler when of mild-steel: in cwts.	13	16	20	23	27	32	34	38	41	46	52	59

Chimneys for Vertical Steam Boilers.—The height of chimney from the ground, for a vertical steam boiler, should not be less than 50 times the internal diameter of the chimney, in order to obtain sufficient draught for the proper and steady combustion of fuel, as well as to discharge the noxious products of combustion at such a height that they will not cause a nuisance.

Table 37.—PROPORTIONS OF BOILERS FOR PORTABLE ENGINES.

Nominal Horse Power.	2.		4.		6.		8.		10.		12.		15.		20.		25.		30.	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
Size across front	2	3	2	7	2	11	3	1	3	3	3	7	3	9	4	0	4	3	4	6
Width of casing	1	9	1	11	2	0	2	4	2	6	2	10	3	0	3	6	4	0	4	3
Height of casing	3	0	3	7	4	0	4	3	4	6	4	8	5	0	5	6	6	0	6	6
Diameter of barrel	1	9	2	2	2	6	2	8	2	9	3	0	3	3	3	7	3	9	4	0
Length of barrel	3	9	4	6	5	8	6	0	6	6	6	9	7	0	7	6	8	0	8	6
Thickness of barrel		$\frac{5}{16}$		$\frac{5}{16}$		$\frac{3}{8}$		$\frac{3}{8}$		$\frac{3}{8}$		$\frac{3}{8}$		$\frac{3}{8}$		$\frac{7}{16}$		$\frac{7}{16}$		$\frac{7}{16}$
Thickness of fire-box		$\frac{3}{8}$		$\frac{3}{8}$		$\frac{3}{8}$		$\frac{3}{8}$		$\frac{7}{16}$		$\frac{7}{16}$		$\frac{7}{16}$		$\frac{1}{2}$		$\frac{1}{2}$		$\frac{1}{2}$
Thickness of fire-box tube plate		$\frac{1}{2}$		$\frac{9}{16}$		$\frac{9}{16}$		$\frac{5}{8}$		$\frac{5}{8}$		$\frac{5}{8}$		$\frac{5}{8}$		$\frac{11}{16}$		$\frac{11}{16}$		$\frac{11}{16}$
Thickness of back tube plate		$\frac{1}{2}$		$\frac{9}{16}$		$\frac{9}{16}$		$\frac{5}{8}$		$\frac{5}{8}$		$\frac{5}{8}$		$\frac{5}{8}$		$\frac{5}{8}$		$\frac{5}{8}$		$\frac{5}{8}$
Thickness of shaped plate		$\frac{3}{8}$		$\frac{3}{8}$		$\frac{3}{8}$		$\frac{7}{16}$		$\frac{7}{16}$		$\frac{1}{2}$		$\frac{1}{2}$		$\frac{1}{2}$		$\frac{9}{16}$		$\frac{9}{16}$
Thickness of arch plate		$\frac{3}{8}$		$\frac{3}{8}$		$\frac{3}{8}$		$\frac{3}{8}$		$\frac{3}{8}$		$\frac{7}{16}$		$\frac{7}{16}$		$\frac{1}{2}$		$\frac{1}{2}$		$\frac{1}{2}$
Number of tubes	12		18		24		28		32		34		40		46		52		60	
Diameter of tubes		$2\frac{1}{2}$		$2\frac{1}{2}$		$2\frac{1}{2}$		$2\frac{1}{2}$		$2\frac{1}{2}$		$2\frac{1}{2}$		$2\frac{3}{4}$		$2\frac{3}{4}$		$2\frac{3}{4}$		$2\frac{3}{4}$
Approximate weight of boiler when of wrought-iron: in cwts.	16		25		30		35		45		54		63		74		88		94	
Approximate weight of boiler when of mild-steel: in cwts.	17		26		31		36		46		56		65		76		90		96	

Table 38.—PROPORTIONS OF RETURN-TUBE BOILERS, FOR SMALL STEAM BOATS, TUGS, &C.

Nominal Horse Power.	5.	6.	7.	8.	10.	12.	14.	15.	16.
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
Diameter of shell	4 0	4 3	4 6	4 9	5 0	5 3	5 6	5 6	5 6
Length of shell	5 6	6 0	6 0	6 6	6 0	7 0	7 0	7 6	8 0
Thickness of shell	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
Diameter of flue	2 0	2 0	2 3	2 3	2 6	2 6	2 9	2 9	2 9
Length of flue	4 0	4 3	4 3	4 9	4 3	5 0	5 0	5 6	6 0
Thickness of flue	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
Number of tubes	26	30	34	36	44	46	50	50	50
Diameter of tubes	$2\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{3}{4}$
Thickness of ends	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{9}{16}$
Thickness of tube-plate of combustion-chamber	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$
Thickness of tube-plate, back of combustion-chamber	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{9}{16}$
Thickness of smoke-box	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$
Depth of combustion-chamber	1 2	1 5	1 5	1 5	1 5	1 6	1 6	1 6	1 6
Diameter of dome	1 9	2 0	2 0	2 3	2 3	2 6	2 6	2 6	2 6
Height of dome	1 9	2 0	2 0	2 3	2 3	2 6	2 6	2 6	2 6
Diameter of funnel	9	9	10	10	10	1 0	1 2	1 2	1 2
Height of funnel	6 0	6 0	8 0	8 0	10 0	10 0	10 0	10 0	10 0
Approximate weight of boiler when of wrought-iron: in cwts.	30	33	45	54	63	70	76	81	86
Approximate weight of boiler when of mild-steel: in cwts.	31	34	46	56	65	72	78	83	88

The Weights of the Boilers given in this and the preceding Tables do not include the weight of their Mountings or Fittings.

Table 39.—Standard Sizes of Lancashire Boilers.

Standard sizes of Ruston Lancashire boilers as illustrated in the frontispiece are given below. The duties are based on the consumption of a good quality steam coal having a calorific value of not less than 13,500 B Th U. Intermediate sizes can be constructed if necessary

Length of Boiler	20′ 0″	24′ 0′	24′ 0″	26′ 0″	28′ 0″	28′ 0″	30′ 0′	28′ 0″	30′ 0′	30′ 0′	30′ 0″	30′ 0″	30′ 0″
Diameter of Boiler	6′ 0″	6′ 0″	6′ 6″	6 6″	6′ 6″	7′ 0″	7′ 0″	7′ 6″	7′ 6	8′ 0″	8′ 6″	9′ 0″	9′ 6″
External Diameter of Flues	2′ 3″	2′ 3″	2′ 6′	2′ 6″	2′ 6′	2′ 9′	2′ 9″	3′ 0″	3′ 0″	3′ 3″	3′ 6″	3′ 9″	4′ 0″
Grate Area in sq ft	21 67	24 9	27 7	29 0	29 0	32 0	32 0	35 0	35 0	38 0	41 0	44 0	47 0
Heating Surface in sq ft	510	630	675	735	795	860	925	940	1000	1085	1160	1230	1310
Normal Evaporation in lb per hour—													
Feed at 60° Fah	2860	3530	3850	4190	4530	4980	5370	5640	6000	6950	8120	9470	10880
From & at 212° Fah	3430	4230	4620	5030	5440	5980	6450	6770	7200	8340	9750	11370	13050
Approximate Weight of Boiler in Cwt —													
80 lb Pressure	139	159	186	197	208	234	247	262	277	290	325	350	410
100 lb Pressure	149	171	208	220	234	271	284	284	302	330	360	410	472
120 lb Pressure	155	178	224	237	252	284	297	314	332	365	418	459	571
140 lb Pressure .	175	200	244	258	273	311	324	338	357	405	466	519	586
150 lb Pressure .	188	215	259	274	290	329	342	357	377	435	492	561	630
160 lb Pressure .	202	231	272	288	304	364	377	390	412	455	527	588	660
170 lb Pressure .	220	250	297	314	330	381	394	413	436	482	546	640	715
180 lb Pressure .	235	267	324	342	358	408	421	433	462	515	570	665	742
190 lb Pressure	251	295	348	367	383	431	444	461	487	540	583	690	782
200 lb Pressure	268	314	370	389	406	457	470	484	512	562	606	710	808
210 lb Pressure	287	335	394	414	421	484	497	509	539	585	626	735	838
Approximate Weight of Fittings in Cwt—													
80 lb Pressure	53	56	58	59	59	65	66	70	71	76	83	91	99
100 lb Pressure .	53	56	58	59	59	65	66	70	71	76	83	91	99
120 lb Pressure	53	56	58	59	59	65	66	70	71	76	83	91	99
140 lb Pressure .	55	58	60	61	61	67	68	72	73	78	85	93	102
150 lb Pressure .	55	58	60	61	61	67	68	72	73	78	85	93	102
160 lb Pressure .	55	58	60	61	61	67	68	72	73	78	85	93	102
170 lb Pressure .	56	59	61	62	62	69	70	74	75	80	87	96	106
180 lb Pressure .	56	59	61	62	62	69	70	74	75	80	87	96	106
190 lb Pressure	56	59	61	62	62	69	70	74	75	80	87	96	106
200 lb Pressure .	57	60	62	63	63	71	72	77	78	83	90	99	109
210 lb Pressure .	57	60	62	63	63	71	72	77	78	83	90	99	109

Table 40.—Paxman "Economic" Boiler

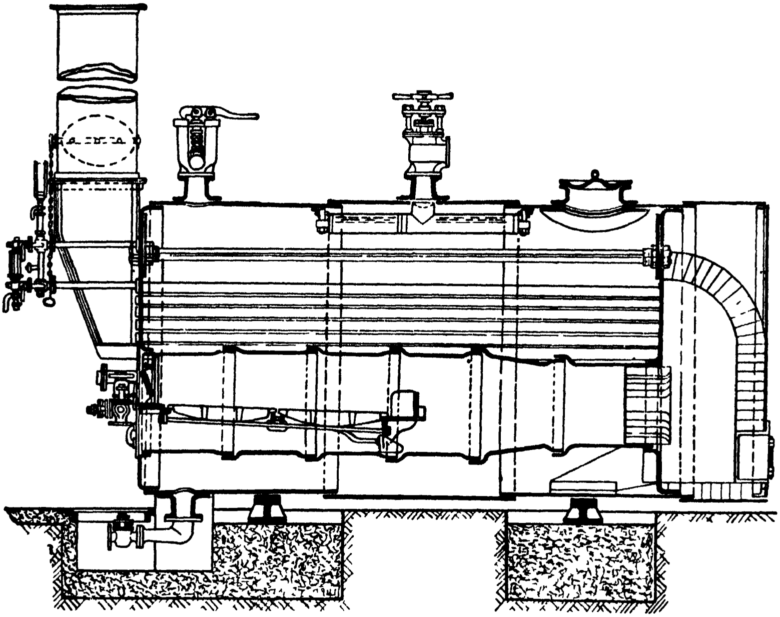
With Single or Double Flues

PRINCIPAL DIMENSIONS OF STANDARD SIZES

Length of Boiler		Diam of Boiler		No of Flues	Diam of Flues		Internal Heating Surface	*Normal Evaporation per hour		Approx Weight of Boiler for a Working Pressure of		Approx Weight of Fittings		Approximate Measurement	
								From Feed at 60° F hr	From and at 212° F hr.	100 lb	120 lb	Un packed	Packed in Case	Boiler	Fittings in Case
ft	in	ft	in		ft	in	sq ft	lb	lb	cwt	cwt	cwt	cwt	cub ft	cub ft
6	5	4	9	1	2	3	150	750	900	43	45	20	23	215	60
7	0	5	0	1	2	4	185	925	1110	48	50	21	24	256	60
8	0	5	0	1	2	6	250	1250	1500	57	59	22	25	290	60
8	6	5	0	1	2	6	265	1325	1590	61	63	27	30	308	60
9	0	5	3	1	2	6	295	1475	1770	66	72	30	34	337	60
9	6	5	6	1	2	9	340	1770	2040	78	84	31	35	398	75
9	6	6	0	1	3	0	420	2100	2520	90	95	33	38	450	91
11	0	6	3	1	3	2	485	2425	2910	108	124	36	41	575	94
12	6	6	6	1	3	2	590	2950	3540	122	139	40	45	680	104
12	6	7	0	2	2	3	690	3450	4140	150	170	54	60	800	110
12	6	7	6	2	2	4	795	3975	4770	182	198	58	64	925	115
14	0	7	6	2	2	6	895	4475	5370	192	214	62	68	1027	135
14	0	8	0	2	2	8	1175	5875	7050	215	255	67	73	1121	155
14	0	8	7	2	2	10	1340	6700	8040	270	282	70	76	1220	181
15	6	8	10	2	3	0	1530	7650	9180	310	330	82	89	1460	217
15	6	9	0	2	3	0	1674	8370	10044	320	345	83	90	1630	218
15	6	9	6	2	3	2	1826	9130	10956	340	365	84	94	1676	220
15	6	9	9	2	3	2	2050	10250	12300	352	388	86	96	1814	222
16	0	10	0	2	3	3	2217	11085	13302	370	410	90	106	1918	232
16	0	10	6	2	3	6	2511	12555	15066	400	440	94	110	2130	240
16	0	11	0	2	3	9	2688	13440	16128	420	470	98	115	2186	248

* The figures given for the evaporative capacity of each boiler are when burning good coal and with good draught and stoking. It is, of course, possible to obtain a much greater evaporation when the draught is ample, and the user is prepared to sacrifice economy to increase the evaporation

AN "ECONOMIC" BOILER.
(Messrs. Davey, Paxman & Co., Colchester.)



The "Economic" boiler shown above is manufactured by Messrs. Davey, Paxman & Co., Colchester, in twenty-one standard sizes, the smallest boiler having a diameter of 4 feet 9 inches, by 6 feet 5 inches, in length, evaporating 900 lbs. of water from and at 212° F. per hour and the largest 11 feet in diameter by 16 feet in length, with an evaporation of 16,128 lbs. per hour. Normal evaporations are given in table 40.

The Tensile Strength of Good Wrought-Iron Boiler-Plates when the strain is applied in the direction in which they are rolled, or along the grain, is 21 tons per square inch of section; when the strain is applied across the grain it is only 18 tons. The tensile strength of Lowmoor and Best Yorkshire-iron plates is 24 tons per square inch of section lengthways of the grain, and 22 tons across the grain. The tensile strength of mild steel boiler-plates averages from 28 to 30 tons per square inch.

Riveted Joints are liable to fracture in 4 different ways: (1.) *The rivets may be shorn off*—the force required to shear a rivet being the shearing strength of the rivet multiplied by the area of the rivet. The strength of rivet-iron to resist shearing is about that of the plate to resist tearing, or 21 tons per square inch of section. The strength of the rivets in a joint, may be found by multiplying the area in square inches of one rivet by the number of rivets, and multiplying the product by 47,000 for ordinary iron rivets, and by 53,760 for mild steel rivets.

(2.) *The plate may tear along the line of rivet-holes* as shown at A B, Fig. 135, that is, between the rivet-holes. The strength of the plate between the rivet-holes is impaired by punching to the extent of 20 per cent.; and the strength to resist fracture between the rivet-holes is found thus :— first find the area of plate between two rivet-holes, which is found by subtracting the diameter of the rivet from the pitch of the rivets in inches, and multiply the remainder by the thickness of the plate in inches, giving the area in square inches between two rivet-holes. Multiply this by 38,700 for wrought-iron plates, when the rivet-holes are punched and by 44,000 when the rivet-holes are drilled. The answer will be the strength of metal left between two rivet-holes.

(3.) *The plate may crush in front of the rivet* as shown at Fig. 136. The resistance offered by a plate to the crushing strain of a rivet, is one and three-quarter times the amount of the tensile strength of that plate, or say 37 tons. The area which resists the crushing strain, is found by multiplying the diameter of the rivet by the thickness of plate in inches; and the strength of the wrought-iron plate between the rivet-hole and the edge of the plate is found thus :—multiply the diameter of the rivet by the thickness of plate in inches, and multiply the product by 82,800.

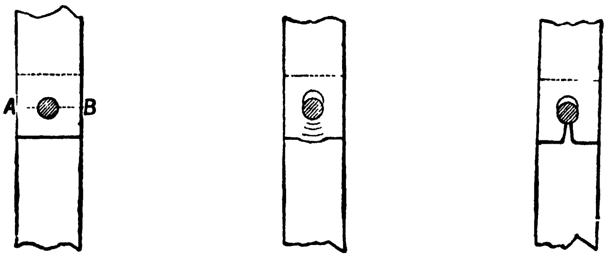


Fig. 135. Fig. 136. Fig. 137.

Figs 135-137.—Fractures of Riveted-Joints.

(4.) *The plate may break across in front of the rivet* as shown at Fig. 137, and the strength opposed to resist this transverse fracture may be found thus: Multiply the square of the distance between the rivet-hole and the edge of the plate, by the thickness of the plate, then divide the product by the diameter of rivet, and multiply the quotient by 48. The answer will be in tons, which multiplied by 2240 gives the strength in lbs.

Example of the above rules.—Required the strength of the riveted joint of two wrought-iron plates, each 41½ inches wide × $\frac{7}{16}$ inch thick, fastened with 20 rivets ¾ inch diameter × 2 inch pitch; in punched holes ¾ inch from edge of plate.

(1.) ·4417 × 20 × 47,000 . Rivets shearing off . . 415,198 lbs.
(2.) 2—75 = 1·25 × ·437 × 38,700 × 20 . . } Tearing between rivet-holes. 422,600 „

(3) ·437 × ·75 × 82,800 × 20	Crushing in front of rivet holes	541,500 lbs
(4.) $\frac{\cdot75^2 \times \cdot437}{\cdot75} = \cdot3274 \times$ 48 × 2240 × 20 .	Breaking across in front of rivet holes . . .	703,800 „
The strength of the solid plate will equal its sectional area × 47,000, or 41½ inches wide × ·437 thick × 47,000 lbs. tensile strength		852,340 „

The Weakest Part of the above Seam is the resistance offered to the rivets shearing off. The strength to resist tearing between the rivet-holes,

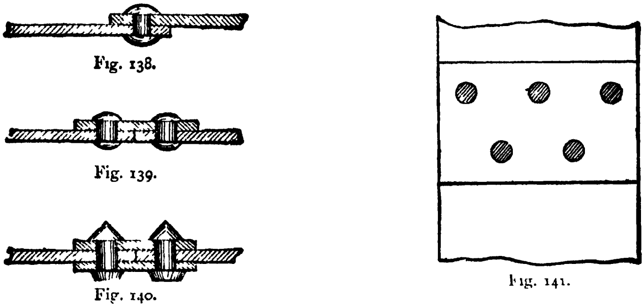


Fig. 138.
Fig. 139.
Fig. 140.
Fig. 141.

Figs 138–141.—Forms of Riveted Joints

is also very small compared with the strength of the solid plate, the strength of the joint with punched holes and single riveted, being only equal to one-half that of the solid plate The efficiency of the joint is the ratio of its strength to that of the solid plate, and is found to be for single-riveting about 56 per cent., and for double-riveting 70 per cent. of the strength of solid plate

Fig. 138 shows a single-riveted lap-joint; Fig. 139 a butt joint with single

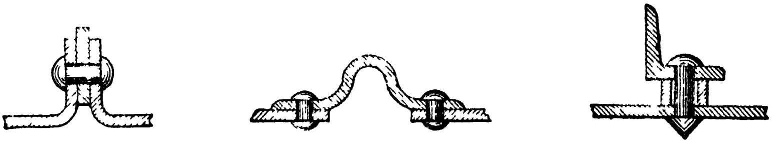


Fig. 142.
Fig 143.
Fig. 144.

Figs. 142–144.—Methods of Strengthening Furnace-Tubes.

covering strip; Fig. 140, a butt-joint with double covering strip; Fig. 141, a double riveted joint with zigzag rivets; Fig. 142, Adamson's flanged seam for furnace-tubes: Fig. 143, Expansion hoop for furnace-tubes; Fig. 144, Angle-iron hoop, or strengthening ring for furnace-tubes.

The Pitch of Rivets for boilers, varies considerably in practice. The proportions of riveted joints given in table 103, page 300, give good results.

Bursting Pressure of Cylindrical Steam Boilers.—To find the strength to resist—in a line parallel to its axis—the internal bursting pressure of a cylindrical boiler shell. *Rule:* Multiply twice the thickness of the plate in inches, by one of the following constant numbers, and divide the product by the diameter of the boiler shell in inches, and the quotient will be the bursting pressure in lbs. per square inch.

26,000 constant number for single-riveted joint of wrought-iron.
32,500 „ „ double-riveted joint of wrought-iron.
40,500 „ „ single-riveted joint of steel.
50,625 „ „ double-riveted joint of steel.

Table 42 has been calculated by these rules. It gives the bursting pressure in pounds per square inch of lap-jointed wrought-iron cylindrical boiler shells, of from 2 feet to 9 feet diameter, of various thickness of plates, both single and double-riveted.

Bursting pressure of Spherical Shells.—To find the bursting pressure in lbs. per square inch, of a wrought-iron spherical shell, take double the bursting pressure of a cylindrical shell, of the same radius and thickness.

The Collapsing-Pressure of Furnace Tubes may be found by the following rule:

Let t = the thickness of the furnace tube in thirty-seconds of an inch.
D = the external diameter of the tube in inches.
L = the length of the tube in inches, or the length between the flanges of a tube with flanged seams.
C = 600 for plain furnace tubes of wrought iron; and 660 when of steel.
C = 1200 for corrugated furnace tubes of steel, and for which D = the greatest external diameter of the tube in inches.

Collapsing-pressure in pounds per square inch =

$$\frac{t^2 \times C}{D \times \sqrt[2]{L}}$$

In the case of oval tubes, the diameter of the greatest circle of curvature is to be substituted for D in this formula.

Test Marks.—The British Standards Institute recommend that each boiler should be permanently and clearly marked on the front end plate with:

Manufacturer's identification marks.
Inspecting authority's stamp.
Date of hydraulic test.
Number of the specification under which boiler was constructed.
Hydraulic test pressure.
Permissible working pressure.

Table 42.—STEAM FLOW.

From *Boiler House Practice.**

Delivery of Steam at Various Pressures.

Weight of steam flowing through a pipe 100 ft. in length with a steady flow and a pressure drop of 1 lb. per hour in lbs.

Gauge Pressure in Lbs.	Pipe Diameters.									
	¾ In.	1 In.	1¼ In.	1½ In.	2 In.	2½ In.	3 In.	4 In.	5 In.	6 In.
10	33·8	68·4	149·4	232·8	471·6	777·0	1,420	3,006	5,564	9,126
20	39·8	80·4	176·4	273·6	554·4	913·8	1,673	3,536	6,546	10,740
30	44·9	90·6	199·2	309·0	626·0	1032·0	1,889	3,991	7,386	12,120
40	49·4	99·6	219·0	340·2	688·8	1136·0	2,080	4,394	8,130	13,344
50	53·5	107·4	237·0	367·8	745·2	1229·0	2,250	4,753	8,796	14,436
60	57·3	115·2	253·8	393·6	798·0	1316·0	2,490	5,090	9,420	15,456
70	60·7	122·4	269·4	418·2	847·2	1397·0	2,557	5,403	9,996	16,410
80	64·1	129·0	283·8	440·4	892·8	1482·0	2,695	5,696	10,536	17,298
90	67·2	135·6	297·6	462·6	936·6	1545·0	2,828	5,976	11,058	18,150
100	70·2	141·6	310·8	483·0	979·2	1613·0	2,954	6,240	11,550	18,956
120	75·8	162·4	336·0	521·4	1057·0	1742·0	3,190	6,738	12,468	20,466
150	83·4	168·0	369·6	576·3	1163·0	1918·0	3,511	7,416	13,728	22,524

Multiplying Factors for Other Lengths and Pressure Drops.

Pressure Drop in lbs.	Length of Pipe.									
	25 Ft	50 Ft.	75 Ft.	100 Ft	125 Ft.	150 Ft.	175 Ft.	200 Ft	250 Ft.	300 Ft.
1	2·0	1·41	1·15	1·0	0·894	0·816	0·752	0·707	0·632	0·577
2	2·82	2·0	1·63	1·41	1·26	1·15	1·07	1·0	0·894	0·816
3	3·46	2·44	2·0	1·73	1·54	1·41	1·31	1·22	1·09	1·0
4	4·0	2·82	2·3	2·0	1·78	1·63	1·51	1·41	1·26	1·15
5	4·47	3·16	2·58	2·23	2·0	1·82	1·69	1 58	1·41	1·29
10	6·32	4·47	3·65	3·16	2·82	2·58	2·39	2·23	2·0	1·82
20	8·94	6·32	5·16	4·47	4·0	3·65	3·38	3·16	2·82	2·58

Length in Feet to be Added to Actual Length for Pipe Inlet and each Globe Valve and Elbow.

	Bore of Pipe.									
	¾ In	1 In	1¼ In	1½ In	2 In	2½ In	3 In.	4 In.	5 In.	6 In.
Inlet and valve .	1·22	2·06	3·06	4·2	6·78	9·75	13·0	20·0	27·7	35·7
Elbow . .	0·81	1·34	2·04	2·8	4·52	6·5	8·65	13·3	18·5	23·8

---

* The Technical Press Ltd, 6/-.

Water-Tube Boilers.—It is essential to economy that water-tube boilers shall have free and rapid circulation of the water, and freedom of expansion in all parts, a large area of fire-grate surface, large steam and water drums, a high temperature in the furnace, and no excess of air-supply to the burning fuel.

The principal types of water-tube boilers in general use may be briefly described as follows:—

The Babcock and Wilcox Water-Tube Boiler has a series of horizontally inclined steam-generating tubes. The steam and water rise from the generating tubes up through vertical connecting boxes, or headers, at the front end into the steam and water drum. The water returns through vertically inclined tubes at the back end of the boiler to the generating tubes.

The Stirling water-tube boiler consists of a lower water drum or mud drum, connected by three banks of steam-generating tubes to three upper steam and water drums connected by circulating tubes. The feed-water enters the rear steam and water drum, and passes down the rear bank of tubes to the bottom water drum.

The Thorneycroft water-tube boiler of the "Speedy" type has an upper steam and water drum connected by two down-take tubes, and by a large number of curved steam-generating tubes, to two lower water drums, one of which is at each side of the fire-grate. They are arranged in two groups, and they enter the steam and water drum above the water-level.

The Yarrow water-tube boiler consists of an upper steam and water drum, and two lower semi-circular water-chambers, one of which is at each side of the fire-grate. The steam drum is connected to the water-chamber by two circulating wings formed of several rows of small straight steam-generating tubes.

The Niclausse water-tube boiler has no rear-headers. The water-tubes are closed at the back end, and are provided with inner circulating tubes. They are so connected at the front end that the inner, or circulating tubes, and the outer, or steam-generating tubes, communicate with separate headers.

Vertical water-tube boilers have a water drum at the bottom, and one or more steam and water drums at the top, connected by numerous rows of either vertical or vertically-inclined steam-generating tubes.

Water-tube boilers are generally very efficient generators of steam. Some results of evaporative tests of different kinds of steam-boilers are given in the following table.

The evaporative efficiency of a steam-boiler is

$$= \frac{\text{Pounds of water evaporated from and at } 212^\circ \text{ Fahr. per pound of coal.}}{\text{Evaporative power of the coal from and at } 212^\circ \text{ Fahr.}}$$

The maximum efficiency of different kinds of steam-boilers under ordinary working conditions without economizers is as follows:

	Efficiency per cent.		Efficiency per cent.
Flash boilers	93	Locomotive boilers	65
Marine return-tube boilers	80	Portable-engine boilers	60
Water-tube boilers	75	Vertical multitubular boilers	60
Lancashire boilers	70	Vertical cross-tube boilers	55

Table 43.—Evaporative Performances of Various Steam-Boilers.

Description of Steam-Boiler.	Coal burnt per square foot of fire-grate surface per hour in pounds.	Water evaporated from and at 212° Fahr. per pound of coal in pounds.	Water evaporated from and at 212° Fahr. per square foot of heating surface per hour, in pounds.
The Thorneycroft water-tube boiler	29·8	12·00	4·70
The Thorneycroft water-tube boiler	66·8	10·29	8·50
The Yarrow water-tube boiler	20·5	11·65	3·96
The Yarrow water-tube boiler	40·4	11·44	7·23
The Babcock and Wilcox water-tube marine boiler	14·2	13·28	4·72
The Babcock and Wilcox water-tube marine boiler	15·3	13·04	4·99
The Stirling water-tube boiler	25·2	10·57	4·48
The Stirling water-tube boiler	39·0	10·80	6·60
The Niclausse water-tube boiler	25·6	10·34	6·34
Water-tube boiler with coiled tubes	18·0	11·25	3·20
Water-tube boiler with vertical tubes	16·0	11·00	3·25
Water-tube boiler with vertically-inclined tubes	19·0	10·70	2·85
Locomotive boiler	92·0	10·50	15·00
Locomotive boiler	112·0	10·00	13·00
Portable engine boiler, loco. type	25·8	8·50	7·15
Portable engine boiler, loco. type	21·3	10·30	7·50
Vertical multitubular boiler	17·0	9·12	9·60
Vertical cross-tube boiler	13·0	8·00	7·50
Cornish boiler, small	15·0	8·25	2·52
Cornish boiler, large	19·0	8·70	5·00
Lancashire boiler, 7 ft. 6 in. × 30 ft.	24·0	8·80	4·50
Lancashire boiler, 8 ft. × 30 ft.	18·5	9·50	5·12
Marine return-tube boiler	27·0	8·50	7·50
Marine return-tube boiler	32·0	10·00	9·10
Flash-boilers, using fuel-oil	—	12·00	6—12
Flash-boilers using fuel-oil	—	16·00	8—18

SAFETY-VALVES.

A Safety-Valve should be capable of discharging considerably more steam than the boiler can generate, by the combustion of all the coal that can be burnt upon its fire-grate, to prevent the blowing-off pressure being materially exceeded, and the area should be proportional both to the fire-grate surface and to the pressure of steam. The lower the pressure the larger must the safety-valve be. When steam flows through an orifice with a square edge such as a safety-valve, its flow is considerably reduced, and the weight in lbs. of steam discharged per minute, per square inch of opening, corresponds nearly with three-fourths of the absolute pressure in the boiler, when that pressure is not less than 25 lbs., or 10 lbs. above the atmosphere. The area of opening requisite for the discharge of any given constant weight of steam, is in inverse ratio of the pressure; that is to say, it requires an orifice of three times larger area, to discharge steam of 30 lbs. pressure, than is required to discharge the same weight of steam per minute at 90 lbs. pressure.

The opening for the escape of steam, through a conical valve with cone of 45°, is about one-third less than the lift.

To find the proper area of a Safety-Valve, multiply the area in square feet of fire-grate surface, by one of the following multipliers, corresponding with the pressure at which the safety-valve is to blow off, and the product will give the area in square inches of that safety-valve; to which must be added the area of the wings of the valve, when the valve is constructed with wings.

Pressure as shown by the steam gauge	10 lbs.,	constant multiplier	1·4
„ „ „ „	15 „	„ „	1·2
„ „ „ „	20 „	„ „	1·04
„ „ „ „	25 „	„ „	·9
„ „ „ „	30 „	„ „	·8
„ „ „ „	35 „	„ „	·72
„ „ „ „	40 „	„ „	·66
„ „ „ „	45 „	„ „	·6
„ „ „ „	50 „	„ „	·56
„ „ „ „	55 „	„ „	·54
„ „ „ „	60 „	„ „	·52
„ „ „ „	70 to 80 „	„ „	·5
„ „ „ „	80 to 100 „	„ „	·48

Direct Load upon the Valve.—When the valve is loaded by a weight or spring, placed direct upon the valve, without the intervention of a lever.

To find the necessary weight in lbs. to attach, or the amount of tension to put upon the spring, to prevent the valve blowing off before the blowing-off pressure is reached, multiply the area of the valve in square inches by the pressure of steam in lbs. per square inch, and to the product add the weight of the valve.

To find the pressure in lbs. per square inch, divide the load in lbs. upon the valve, by the area of the valve in square inches.

Safety Valve with Lever.—The centre of gravity of the lever, is the point at which it will balance, when placed upon a knife-edge. In Fig. 145

F is the fulcrum, or joint where the lever is fixed, V is the centre of the valve, W is the weight.

The best angle for the seat of the valve is 45°; the width of mitre should not exceed $\frac{1}{16}$ inch; the lift of the valve should not exceed $\frac{1}{10}$ inch; the distance between the fulcrum and the centre of the valve, should equal the diameter of the valve; the pivot should bear upon the valve considerably below the level of the valve-seat. When a weight is used the total length of lever should equal one-third the diameter of the boiler; when the lever is held down by a spring-balance, the distance between the fulcrum and the centre of the valve should equal the diameter of the valve, and the distance between the fulcrum and the spring-balance, should equal as many times the diameter of the valve, as there are square inches in its area.

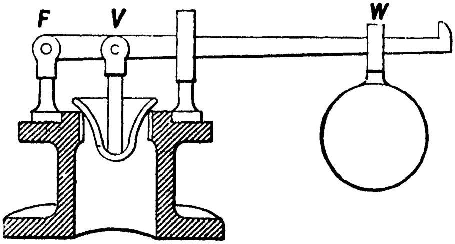


Fig. 145 --Section of a Safety-Valve.

Safety-Valve Loaded by a Lever and Weight.—When a lever and weight are employed to load a valve, it is necessary to find the resistance due to the weight of the lever and the valve. This may be ascertained by securing the valve to the lever with a piece of wire, and attaching a spring balance directly over the centre of the valve, which will give the load due to the weight of the valve and the action of the lever. This result divided by the area of the valve in square inches, will give the pressure in lbs. per square inch, at which the steam will raise that valve.

To calculate the action of the lever when the above method cannot be employed, *Approximate Rule:* Multiply the weight in lbs. of the lever, by the distance between the fulcrum and the centre of gravity, and divide the product, by the distance between the fulcrum and the centre of the valve; which will give the approximate resistance in lbs. due to the action of the lever, to which result add the weight of the valve and pivot.

To find the pressure in lbs. per square inch, at which the valve will begin to blow off:—

1. Multiply the weight in lbs. of the ball, by the distance in inches it is placed from the fulcrum.

2. Multiply the weight in lbs. of the lever, by the distance in inches between the centre of gravity and the fulcrum.

3. Multiply the weight in lbs. of the valve, by the distance in inches between the centre of the valve and the fulcrum.

4. Multiply the area of the valve in square inches, by the distance in inches between the centre of the valve and the fulcrum, then add together the first 3 products, and divide the sum by the 4th product.

To find the position of the weight on the lever, so that the safety-valve will blow off at a given pressure:—

1. Multiply the weight in lbs. of the lever, by the distance in inches between the centre of gravity and the fulcrum.

2. Multiply the weight in lbs. of the valve, by the distance in inches between the centre of the valve and the fulcrum.

3. Multiply the area of the valve in square inches, by the pressure of the steam in lbs. per square inch, and multiply the product by the distance in inches between the centre of the valve and the fulcrum; then add together the first two products, and subtract the sum from the 3rd product, and divide the remainder by the weight of the ball in lbs.

To find the weight to place on the lever, so that the valve will blow off at a given pressure:—Multiply the area of the valve in square inches, by the required pressure of steam in lbs. per square inch, from which result deduct the weight of the valve and action of the lever in lbs.; then multiply by the distance from the fulcrum to the centre of the valve in inches, and divide the product by the distance in inches, between the fulcrum and the point of the lever at which the weight is placed.

PROPORTIONS OF STEEL SPRINGS.

Spiral Springs.—The proportions of spiral springs for safety valves loaded with direct springs, may be determined by the following rules:—

The internal diameter of the coil, should equal 4 times the thickness of the steel of which the spring is composed.

The lift of safety valves for all sizes, may be taken at one-tenth part of an inch.

The compression or extension of the spring, to produce the initial load, should be forty times the lift of the valve, or 4 inches for all sizes of valves with the above lift.

To find the diameter of round steel, or side of square of square steel, for springs:—

Find the load, by multiplying the area of the safety-valve in square inches, by the pressure of the steam in lbs. per square inch; then multiply the load by the diameter of the coil, from centre to centre of the steel; divide the quotient by the constant number 3 for round steel, or by the constant number 4·29 for square steel, and the cube root of the quotient will give the size of steel in sixteenths of an inch, that is, the diameter when round, and the side of the square when square.

To find the compression or extension of one coil in inches:—Cube the diameter in inches of the coil (from centre to centre of the steel), then multiply by the load in lbs., and divide the product by the product of the fourth power of the diameter (or side of square if square) of the steel in sixteenths of an inch, multiplied by the constant number 22 for round steel, and 30 for square steel.

To find the pitch of a spiral spring:—The distance between neighbouring coils should be equal to twice the compression (or extension as the case may be), found by the last rule, and the pitch will be twice the compression added to the diameter of the steel when round, or the side of the square when square.

To find the number of coils:—Divide the initial compression of spring (or 4 inches for all sizes) by the amount of compression, or extension of one coil (found by the above rule), which will give the effective number of coils.

To find the length of spring, multiply the number of coils found by last rule by the pitch of spiral, and add two more coils, to allow for the two end coils serving as bases for the spring.

The above rules are for valves loaded with direct springs, but the same rules apply to springs acting at the end of levers, in which case the lift of the end of the lever where the spring is attached, must be taken instead of the lift of the valve.

Laminated Springs for Locomotive Engines, railway carriages and waggons, and conveyances.—The thickness of steel plate for springs under 3½ to 4 feet span, should not exceed ¼ inch in the smaller, and from 5/16 to ⅜ inch in the larger sizes; for larger spans the thickness is generally ½ inch, with the two top plates ⅝ inch thick. The deflection per ton of load, is about ½ inch for railway waggons, ¾ to 1 inch for locomotive engines, 1½ inch for horse boxes, and from 1¾ to 2¼ inches for railway carriages. The following rules can be used for laminated or plate springs.

Let D = the deflection in sixteenths of an inch per ton load.
S = the span of the spring in inches when loaded.
b = the breadth of the spring plate in inches, considered uniform.
t = the thickness of plates in sixteenths of an inch.
n = the number of plates.
W = the working strength of spring in tons, or safe load.

Then

$$W = \frac{n\,b\,t^2}{11{\cdot}3\ S}$$

$$D = \frac{1{\cdot}66\ S^3}{n\,b\,t^3}$$

$$n = \frac{11{\cdot}3\ S\,W}{b\,t^2}$$

and n necessary to a given elastic flexure, span, and size of plates =

$$n = \frac{1{\cdot}66\ S^3}{D\,b\,t^3}$$

CHIMNEYS FOR FACTORY STEAM BOILERS.

The source of power for the draught of a chimney, is the difference in weight of a vertical column of cool air outside the chimney, compared with that of a vertical column of the heated gases inside the chimney. These two columns of air being of unequal weight, motion ensues. The best draught takes place, when the temperature of the gases inside the chimney is at 552°, which weighs only one-half the weight of the air outside the chimney when at 62°. A quantity of heat is absorbed in producing draught, but only about one-fourth the quantity of the heat is required to raise 1 lb. of air one degree, which is required to raise 1 lb. of water one degree, and the heat carried off by the gases may be found thus: Multiply the weight of air per lb. of coal, by the difference in temperature between the gases in the chimney and the external air, and multiply the product by ·238. The quantity of air required is 24 lbs. for each lb. of fuel. The usual rate of combustion is from 14 to 26 lbs. of coal per square foot of grate-area per hour in Cornish and Lancashire boilers.

Proportions of Brick Chimneys—For an ordinary factory chimney, where three or four boilers are installed, the thickness of brickwork is 9 inches at the top; 14 inches at a distance of one-fourth the height from the top; 18 inches at one-half the height; 23 inches at a distance of three-fourths the height from the top; and 28 inches at the base.

To find the area in square feet at the top of a chimney for a given boiler: *Rule*, multiply the area of the fire-grate surface in square feet by ·80, and divide the product by the square root of the height of the chimney in feet.

To find the maximum horse-power of a chimney, when the inside area at the top, and the height, are given, divide the area in square inches by 70, and multiply the result by the square root of the height in feet. This will give the maximum horse-power, but a chimney should always be made about one-third larger than necessary, to allow for contingencies.

Flues.—The horse-power of a chimney reduces with the length of flue. The power with longer flues than 50 feet, may be found by multiplying the horse-power in the following table by ·8 for flues 100 feet, by ·7 for flues of 200 feet, and by ·6 for flues of 500 feet in length, from the furnace to the chimney bottom.

Table 44.—MAXIMUM HORSE-POWER OF FACTORY CHIMNEYS, WITH FLUES 50 FEET LONG IN CIRCUIT FROM THE FURNACE TO THE BOTTOM OF THE CHIMNEY.

Size at the Top, Inside.		HEIGHT, 40 FEET.		HEIGHT, 50 FEET.		HEIGHT, 60 FEET.		HEIGHT, 70 FEET.		HEIGHT, 80 FEET.		HEIGHT, 90 FEET.		HEIGHT, 100 FEET.		HEIGHT, 120 FEET.	
		Round.	Square.	Round	Square.	Round.	Square	Round.	Square.	Round.	Square.	Round.	Square.	Round.	Square.	Round.	Square.
ft.	in.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.
1	3	15	19	17	21												
1	6	22	28	25	32	27	34										
1	9	30	38	34	43	37	47	40	50	43	55						
2	0	40	50	44	56	49	62	53	67	57	73	60	76				
2	3	50	64	56	71	62	79	67	85	72	92	76	97				
2	6	63	80	70	80	77	98	83	106	89	114	94	120	100	128		
2	9			85	108	94	120	101	126	108	138	114	146	122	156		
3	0			101	126	111	142	120	153	129	165	136	174	145	185	158	200
3	6							163	208	175	224	185	237	197	252	214	274
4	0									229	293	242	310	258	330	281	360
4	6									291	373	307	393	327	419	356	456
5	0											378	484	403	516	439	562
5	6											458	587	488	625	531	680
6	0											546	700	581	744	633	810

The Height of Factory Chimneys in towns and populous districts should not be less than 90 feet.

A Lightning Conductor consisting of a $\frac{5}{8}$ inch copper wire-rope should be fixed, with fastenings spaced 6 feet apart, on the outside of every Factory Chimney. Insulators should not be used. Height of point above the Chimney Top = to the inside Diameter of the Chimney. Earth connection, not less than 7 yards; the wire-strands should be unwound and spread out so as to expose as much surface to the soil as possible, which should be permanently damp; or the wire-rope may terminate in a water pipe or well

THE PREVENTION OF SCALE IN STEAM BOILERS.

Hardness of Water is caused by the water coming in contact with various mineral substances, as it passes over or through the ground, and which it partially dissolves and holds in solution. These substances are chiefly sulphate of lime, bicarbonate of lime, and carbonate of magnesia. These, as well as various other impurities, are contained more or less in all river, lake, and well water. The action of heat in a boiler makes these substances insoluble, and causes their deposit on the boiler-plates in the form of scale, which, being a non-conducting material, retards the transmission of heat from the iron to the water, and also renders the plates liable to be burnt, by preventing the water from coming in contact with the plates. The loss of fuel caused by incrustation seldom exceeds 5 per cent. and could be approximately 2 per cent. with scale 1/16 inch in thickness. For softening water and preventing incrustation, pure caustic soda has been found to be the most effective ; its strength should be 98 per cent., that is, containing only 2 per cent. impurities. Some caustic soda has only 60 per cent. strength, and contains common salts and sulphur salts, which injure the boiler plates. The pure caustic soda in powder should be dissolved in water, and introduced continually with the feedwater, by connecting the suction-pipe of the pump with the vessel containing the composition. The proper amount is, for very hard water, 1 oz. to every 5 gallons of water, and for water of medium hardness 1 oz. for every 10 gallons, and for fairly good water 1 oz. for every 15 gallons. In using caustic soda, the boiler should be frequently blown off.

Feed-Water Treatment.—Feed-water is most effectively treated before the water enters the boiler and advice should be obtained from a competent person following an analysis of the water.

Proportions of Fire-Bars.—Fire-bars should be as short as convenient; thin bars keep cooler, stand the fire better, and do not twist so much as thick ones. The dimensions for all lengths of bars (except in the middle, which is given below) are :—

Thickness at the top = ¾ inch; thickness at the bottom = ⅜ inch; the sides to be parallel at the top to a depth of about ⅝ inch, and then to be tapered downwards; ends and centre rib 1¼ inches thick, so as to leave an air space of ½ inch; ends 1½ inches deep × 1⅜ inches long.

Length of fire-bar, in inches . . .	12	15	18	21	24	27	30	33	36	39	42	45	48
Depth at the centre, in inches . . .	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼	4½	4¾	5
Weight of the bar, in lbs.	5	7	8	10	12	15	17	19	22	26	29	32	36

THE CARE AND MANAGEMENT OF CORNISH AND LANCASHIRE BOILERS.

INSTRUCTIONS TO BOILER ATTENDANTS.

Getting up Steam.—Warm the boiler gradually. Do not get up steam from cold water in less than six hours. If possible, light the fires overnight.

Nothing turns a new boiler into an old one sooner than getting up steam too quickly. It hogs the furnace tubes, leads to grooving, strains the end plates, and sometimes rips the ring-seams of rivets at the bottom of the shell.

Firing,—Fire regularly. After firing, open the ventilating grid in the door for a minute or so. Keep the bars covered right up to the bridge. Keep as thick a fire as the quality of coal will allow. Do not rouse the fires with a rake. Should the coal cake together, run a slicer in on the top of the bars and gently break up the burning mass.

It has been found by repeated trials, that, under ordinarily fair conditions, no smoke need be made with careful hand-firing.

Cleaning Fires and Slacking Ashes.—Clean the fires as often as the clinker renders it necessary. Do not slack the clinkers and ashes on the flooring plates in front of the boiler, but draw them directly into an iron barrow and wheel them away.

Slacking ashes on the flooring plates corrodes the front of the boiler at the flat end plate, and also at the bottom of the shell where resting on the front cross wall.

Feed-Water Supply.—Set the feed-valve so as to give a constant supply, and keep the water up to the height indicated by the water-level pointer.

There is no economy in keeping a great depth of water over the furnace crowns, whilst, at the same time, the steam-space is reduced thereby, and the boiler is rendered more liable to prime. Nor is there any economy in keeping a very little water over the furnace-crowns, whilst the furnaces are thereby rendered more liable to be laid bare.

Glass Water-Gauges.—Blow through the test-tap at the bottom of the gauge frequently, as well as through the tap in the bottom neck, and the tap in the top neck twice daily. These taps should be blown through more frequently when the water is sedimentary, and whenever the movement of the water in the glass is at all sluggish. Should either of the thoroughfares become choked, clean them out, and see that the water rapidly rises to working level in the gauge glass. Keep gauge glass clean and renew as necessary. Always test the glass water-gauges thoroughly the first thing in the morning before firing up.

It does not follow that there is plenty of water in the boiler because there is plenty of water in the gauge-glass. The passages may be choked. Also, empty gauge-glasses are sometimes mistaken for full ones, and explosions have resulted therefrom. Hence the importance of blowing through the test-taps frequently.

Blow-out Taps.—Open the blow-out tap in the morning. If the water be sedimentary, run down half an inch of water at each blowing. If not sedimentary, merely turn the taps round. A boiler can be safely worked with water having a density of $\frac{1}{32}$ equivalent to 5 ozs. of solids per gallon or 218 grains per lb. Density can be ascertained by means of a salinometer or hydrometer. See that the water is at the height indicated by the water-level pointer at the time of opening the scum tap. Do not neglect blowing out for a single day, even though anti-incrustation compositions are put into boiler.

Water should be blown from the bottom of the boiler when steam is not being drawn off, so that the water may be at rest and the sediment have an opportunity of settling. Water should be blown from the surface when steam is being drawn off, so that the water may be in ebullition and the scum floating on the top.

Safety-Valves.—Lift each lever safety-valve by hand in the morning before setting to work, to see that it is free. The best method of testing a safety valve is to allow the steam pressure to rise to just above working pressure. If there is a low-water safety valve, test it occasionally by lowering the water level to see that the valve begins to blow at the right point. When the boiler is laid off, examine the float and lever and see that they are free, and that they give the valve the full rise.

If safety-valves are allowed to remain in one position they may get set fast.

Shortness of Water.—In case the boiler should be found to be short of water, draw the fires, if practicable, and draw them quickly, beginning at the front. In some cases it may be more convenient to smother the fires with ashes or with anything else ready to hand. If the fires are not drawn, leave the furnace doors open, turn on the feed, lower the dampers, shut down the stop-valve if the boiler be one of a series, and relieve the weight on the safety-valve so as to blow off the steam. Warn passers-by from the front of the boiler. Drawing the fires must be done with discretion, and ought not to be attempted if the furnace crowns have begun to bulge out of shape.

Flue Explosions are liable to occur when boilers are lying under banked fires, and can usually be attributed to an accumulation of explosive gases owing to restricted draught. Explosions may also be due to badly constructed flues which form pockets in which gases can lodge. The former can be prevented by keeping the dampers slightly open or by drilling a few holes in the damper plate, and the only remedy for the latter is to overhaul and reconstruct the flues. Explosions have been known to occur following a very heavy charge of fuel with the dampers down; such a condition can be obviated by attention to the draught supply.

Use of Anti-Incrustation Compositions.—Do not use any of these without the advice of an engineer familiar with steam raising problems. If used, never introduce them in heavy charges at the manhole or safety-valve, but in small daily quantities along with the feed water.

Many furnace-crowns have been overheated and bulged out of shape through the use of anti-incrustation compositions, and in some cases explosions have resulted.

Corrosion and Scale.—While many theories regarding corrosion have been, and continue to be, advanced, it is generally agreed that the causes of corrosion are often of a most complex character. The steam-user knows only too well that corrosion takes place, and no matter what the cause he will desire to check deterioration of existing plant and prevent it starting in new. For this purpose a compound, manufactured by Messrs. J. Dampney and Co., Britannic Works, Newcastle-on-Tyne, termed "Apexior," can be recommended. This preparation is applied to the bare metal of plates and tubes in the same manner as a paint, and the makers claim that corrosion from whatever cause will be prevented.

The problem of scale is, of course, quite different from corrosion and no internal treatment can possibly reduce the amount of solids introduced into a boiler with the feed water. What the compound actually does is to make it difficult for the scale forming salts to adhere to the treated metal, thus preventing the adhesion of scale and enabling deposits to be easily removed.

Emptying the Boiler.—Do not empty the boiler under steam pressure, but cool it down with the water in; then open the blow-out tap and let the water pour out. To quicken the cooling the damper may be left open, and the steam blown off through the safety-valves. Do not on any account dash cold water on to the hot plates. But, in cases of emergency, pour cold water in before the hot water is let out, and mix the two together so as to cool the boiler down gradually and generally, and not suddenly and locally.

If a boiler is blown off under steam pressure, the plates and brickwork are left hot. The hot plates harden the scale, and the hot brickwork hurts the boiler. Cold water dashed on to hot plates will cause severe straining by local contraction, sometimes sufficient to fracture the seams.

Cleaning out the Boiler.—Clean out the boiler at least every two months and oftener if the water be sedimentary. Remove all the scale and sediment as well as the flue dust and soot. Show the scale and sediment to the engineer. Pass through the flues, and see not only that all the soot and flue dust have been removed, but that the plates have been well brushed. Also see whether the flues are damp or dry, and, if damp, find out the cause. Further, see that the thoroughfares in the glass water-gauges and in the blow-out elbow pipe, as well as the thoroughness and the perforations in the internal feed dispersion pipe are quite free from scale and deposit. Take the feed pipes out of the boiler if necessary to clean them thoroughly. Take the taps and the feed valve to pieces, examine, clean, and grease them, and if necessary grind them in with a little fine emery or glass powder. Examine the fusible plugs. Do not put any blocks under the pipes in the hearth pit.

Putting blocks under the pipes in the hearth pit robs them of their spring, strains them, and sometimes breaks them.

Preparation for Entire Examination.—Have the boiler cooled and carefully cleaned out as explained above. Show both scale and sediment to the inspector, as well as the old cap of the fusible plug, and tell him of any defects that may have manifested themselves in working, and of any repairs or alterations that may have been made since the last examination.

Unless a boiler be suitably prepared, a satisfactory entire examination cannot be made. Inspectors are sent at considerable expense to make entire examinations, and it is a great disappointment when their visits are wasted from want of preparation. Boiler Insurance Companies are always prepared to afford information to boiler attendants by means of printed report , and to help them in the discharge of their duties, and expects them in return to do all they can to promote a thoroughly sound inspection of the boilers under their charge.

Fusible Plugs.—Keep these free from soot on the fire side, and from incrustation on the water side. Change the fusible metal once every year, at the time of preparing for the Insurance Companies' Inspector's annual entire examination.

If fusible plugs are allowed to become incrusted, or if the metal be worked too long, they become useless, and many furnace crowns have rent from shortness of water, even though fitted with fusible plugs.

Water Hammer and Priming.—Priming frequently occurs in overloaded boilers and is the violent ebullition of water. It is said to occur when an undue quantity of moisture is carried off with the steam. Sudden demands for excessive quantities of steam is the most common cause, but it may also be due to an increase in water level with a reduction of water surface area and steam space. Dirty and greasy water is another source of priming.

Water hammer will be found to occur when steam is admitted to a cold pipe either containing water or retaining condensed steam. When steam comes into contact with water at a lower temperature condensation takes place and a partial vacuum is formed, with the result that the water may be carried through the pipe at a very high velocity. It is possible to cause water hammer in correctly installed steam pipes by admitting steam faster than the condensate can be removed. If steam is admitted to a pipe quite free from water and the condensate is removed before it can accumulate then water hammer cannot occur. In order to prevent water hammer steam pipes must be arranged in such a manner that it is impossible for water to collect in any part of the steam system, and so that all condensate will be automatically removed by suitable steam traps.

Boiler Noises are fairly common with all types of boilers. Humming and vibratory sounds can usually be traced to a thin spot in the fuel through which a rush of air recurs to set up vibrations. Another source of humming is a badly fitting mid-feather wall in the downtake chamber of Cornish and Lancashire boilers. The remedy for the former is careful attention to draught and firing conditions, and the latter calls for a well-constructed wall with the minimum of clearance between the end-plate of the boiler and the face of the brickwork.

General Keeping of Boiler.—Polish up the brass and other bright work in the fittings. Sweep up the flooring plate frequently. Keep ashes and water out of the hearth-pit below the flooring plates. Keep the space on the top of the boiler free, and brush it down once or twice a week. Take a pleasure in keeping the boiler and the boiler-house clean and bright, and in preventing smoke.

Wood Fuel for steam boilers requires one-third more grate-surface, and two-thirds more cubical space in the furnace, than is required for coal, for equal generation of steam. Two cords of wood will evaporate about the same quantity of water as one ton of coal. A cord of dry pine-wood, 4 feet × 4 feet × 8 feet = 128 cubic feet, weighs 17 cwt.

Expansion of Water by Heat.—Water attains its maximum density at 39°·1 Fahr.—or say 40° Fahr.—from which point, any rise or fall of temperature is accompanied by expansion.

Temperature.	Volume.	Temperature.	Volume.
12° Fahr.	1·0024	110° Fahr.	1·0100
22°	1·0001	120°	1·0120
32° Freezing point	1·0003	130°	1·0146
40°	1·0000	140°	1·0177
50°	1·0004	150°	1·0206
62° Mean temperature	1·0012	160°	1·0240
70°	1·0023	180°	1·0297
80°	1·0038	212° Boiling point	1·0460
90°	1·0053	250°	1·0592
100°	1·0074	300°	1·0863

Sea Water requires more heat to boil it, than is required to boil fresh water. No salt passes away with the steam. Its average boiling point is 213·2° F. The proportion of salt held in solution is $\frac{1}{33}$ part of its weight, or about 4 ounces of salt per gallon of sea water. The point of saturation is $\frac{12}{33}$, when the water is full of salt, and will hold no more. Salt water varies in density, and in the nature of its ingredients in different seas. The composition of average sea water is—water, 96·6 parts: chloride of sodium 2·6; chloride of magnesia, ·4; sulphate of soda, ·37; carbonate of lime, ·02; sulphate of lime, ·01. The ice of sea water contains no salt.

SECTION V

HEAT, WARMING AND VENTILATING: MELTING, CUTTING, AND FINISHING METALS: ALLOYS AND CASTING: WHEEL-CUTTING: SCREW-CUTTING, &c.

SECTION V.

HEAT, WARMING, AND VENTILATING; MELTING, CUTTING, AND FINISHING METALS; ALLOYS AND CASTING; WHEEL-CUTTING; SCREW-CUTTING, &c.

HEAT.

Unit of Heat.—The British Thermal Unit (B.H.U.) is the heat required to raise the temperature of 1 lb. of water at 60° F. through 1° F. at constant pressure. A mean thermal unit is $\frac{1}{180}$th of part of the heat required to raise the temperature of 1 lb. of water from 32° F. to 212° F. under a constant pressure of 14·7 lb. per sq. in.

Table 45.—Specific Heat of Solid and Liquid Bodies, being the fraction of a Unit of Heat necessary to Heat one pound of the Body one degree Fahrenheit from about 60 degree Fahrenheit.

Water at 60°	1·000	Marble	·215
Ether	·660	Chalk	·214
Pine wood	·650	Sulphur	·202
Alcohol	·620	Graphite, natural	·201
Oak	·570	Coke	·200
Oil	·520	Brickwork and masonry	·191
Ice	·504	Glass	·190
Birch wood	·480	Phosphorus	·182
Steam, gaseous	·475	Burnt clay	·180
Oil of turpentine	·472	Carbonate of iron	·180
Beeswax	·450	Cast-iron	·129
Petroleum	·434	Cast-steel	·118
Nitric acid	·426	Wrought-iron	·113
Sulphuric acid	·333	Nickel	·108
Spermaceti	·320	Cobalt	·106
Steam, saturated	·305	Zinc	·095
Nitrate of soda	·278	Copper	·095
Coal	·277	Brass	·093
Charcoal	·263	Silver	·057
Carbonic oxide	·247	Tin	·056
Nitrogen	·244	Cadmium	·056
Carbon	·241	Antimony	·050
Air	·237	Mercury	·033
Salt	·225	Gold	·032
Oxygen	·218	Platinum	·032
Carbonic acid	·216	Lead	·031
Quicklime	·216	Bismuth	·030

Specific Heat is not constant at all temperatures, but for practical purposes can be taken as the number of units of heat necessary to heat one pound of the body 1° F., water being used as the standard of comparison. Thus, to heat 100 lbs. of water 80° requires 100 × 80 = 8000 units of heat, and to heat the same weight of wrought-iron requires 100 × 80 × 1·13 = 904, or only about ⅑th of the heat necessary for the same weight of water.

Table 46.—EXPANSION OF LIQUIDS AND GASES IN VOLUME BY THE ADDITION OF HEAT FROM 32° TO 212° F.

1000 parts of mercury become	1018
1000 parts of water become	1046
1000 parts of salt water become . . .	1050
1000 parts of oil become	1080
1000 parts of alcohol become	1110
1000 parts of air become	1366
1000 parts of hydrogen become . . .	1366
1000 parts of nitrogen become	1366
1000 parts of carbonic acid become . .	1368
1000 parts of sulphurous acid become . .	1384

Table 47.—HEAT-CONDUCTING POWER OF METALS, &c.—LATENT HEAT.

(Wiedemann.)				Latent Heat of Liquefaction or units of Heat absorbed by one lb. of the substance in Melting from Solid to Liquid.	
Silver . .	100	Platinum . .	8·4		
Copper . .	73·6	German Silver .	6·3		
Gold . .	53·2	Bismuth . .	1·8	Lead . .	9·7
Brass . .	23·6	Marble . . .	2·4	Bismuth . .	22·7
Tin . .	14·5	Porcelain . .	1·2	Tin . . .	25·6
Iron . .	11·9	Fire Clay . .	1·1	Zinc . . .	50·6
Steel . .	11·6	Terra Cotta .	1·1	Silver . .	38·0
Lead . .	8·5	Water . . .	·9	Cast-iron . .	233·0

Person & Clement.

Table 48.—EXPANSION IN LENGTH OF METALS, &c., BY HEAT PER DEGREE FAHRENHEIT FROM 32°.

Fire bricks . . .	·00000235	Roman cement . .	·0000080
Stock bricks . .	·00000306	Copper	·0000101
Granite	·00000439	Bronze and gun metal	·0000104
Glass	·00000460	Brass	·0000106
Platinum . . .	·00000484	Gold	·0000108
Antimony	·00000617	Silver	·0000112
Cast-iron . . .	·00000650	Tin	·0000132
Steel	·00000668	White solder . .	·0000143
Wrought-iron . .	·00000681	Lead	·0000159
Iron wire	·00000745	Zinc	·0000173
Bismuth	·00000762	Ice, from −17° to +30°	·0000286

Table 49.—RADIATION, ABSORPTION AND REFLECTION OF HEAT. FROM THE EXPERIMENTS OF PROVOSTAGE AND DESAINS.

	Radiating and Absorbing Power.	Reflecting Power.
Smoke-blackened surface	100	0
Carbonate of lead	100	0
Writing paper; ivory; jet; marble	98	2
Glass	90	10
China ink; ice	85	15
Gum lac	72	28
Silver-foil, on glass	27	73
Cast-iron, polished brightly	25	75
Mercury	23	77
Wrought-iron, polished	23	77
Zinc, polished	19	81
Platinum, polished; also steel	17	83
Tin	14	86
Metallic mirrors, slightly tarnished	17	83
Brass, cast, imperfectly polished	11	89
Brass, hammered, dead polished	9	91
Brass, highly polished	7	93
Brass, cast	7	93
Copper, coated on iron	7	83
Copper, varnished	14	86
Copper, hammered or cast	7	93
Gold plating	5	95
Gold, deposited on polished steel	3	97
Silver, hammered and well polished	3	97
Silver, cast and well polished	3	97

Superficial expansion or expansion in two directions, is twice the linear expansion; and cubical expansion, or expansion in three directions, is three times the linear expansion.

The Quantity of Heat given in Table 50 for each material named, is deduced from experiments on the transmission of heat through plates of metal, which were heated on one side by hot water, and cooled on the other side by water at a low temperature. The quantity of heat in units, transmitted through one square foot of plate, per hour, may be found thus: subtract the temperature of the cooler side, from that of the hotter side of the plate, then multiply the result by the number in Table 50 corresponding to the material used, and divide the product by the thickness of plate. Thus an iron plate 2 inches thick, having a temperature of 60° on one side and 80° on the other, will transmit $80-60 = \frac{20 \times 230}{2} = 2300$ units of heat, per square foot per hour.

Table 50.—Quantity of Heat in Units transmitted per square foot per Hour, through a Plate 1 inch thick, the difference of Temperature between the two Faces being 1° F.—from the Experiments of Peclet.

Materials.	Quantity of Heat in Units.	Materials.	Quantity of Heat in Units.
Gold	625	Gutta percha	1·37
Platinum	600	India rubber	1·36
Silver	595	Brick dust, sifted	1·33
Copper	520	Coke, powdered	1·29
Iron	230	Iron filings	1·26
Zinc	225	Cork	1·15
Tin	178	Chalk, powdered	·86
Lead	113	Wood charcoal, powdered	·63
Marble	24	Straw, chopped	·56
Stone	14	Coal, small sifted	·54
Glass	6·6	Wood ashes	·53
Terra cotta	4·8	Mahogany dust	·52
Brickwork	4·8	Canvas hemp, new	·41
Plaster	3·8	Calico, new	·40
Sand	2·17	White writing paper	·34
Oak, across fibre	1·7	Cotton wool & sheep's wool	·32
Walnut, along fibre	1·4	Eiderdown	·31
Fir, along fibre	1·37	Gray blotting paper	·26

HEATING ROOMS BY HOT WATER.

A Hot Water Boiler with its flow and return pipe, resembles an inverted syphon; the motive power in the circulation of hot water, is the difference in weight between the columns of water, ascending from the boiler through its top outlet, or flow pipe, and returning to the boiler through its bottom inlet, or return pipe. As the water in the boiler is heated it expands, becomes lighter and ascends to the top of the boiler in the direction of the flow pipe, and is replaced by colder and consequently heavier water from the bottom or return pipe; this in turn gets heated, ascends, and is replaced by more cold water from the return pipe, and this circulation continues so long as the fire is kept up, the hot water continually ascending, and the cold water descending. The following tables for heating rooms by hot water will be found useful in connection with heating problems.

Table 51.—DIFFERENCE IN WEIGHT OF TWO COLUMNS OF WATER, EACH 1 FOOT HIGH AT VARIOUS TEMPERATURES; ASSUMED ACTUAL TEMPERATURES FROM 170° TO 190° F.

Difference in Temperature of the two Columns.	Diameter of the Pipe.				Difference in Weight of the Columns per Square Inch.
	1 Inch.	2 Inch.	3 Inch.	4 Inch.	
Fahrenheit.	Grains.	Grains.	Grains.	Grains.	
2°	1·5	6·3	14·3	25·4	2·028
4°	3·1	12·7	28·8	51·1	4·068
6°	4·7	19·1	43·3	76·7	6·108
8°	6·4	25·6	57·9	102·5	8·160
10°	8·0	32·0	72·3	128·1	10·200
12°	9·6	38·5	87·0	154·1	12·264
14°	11·2	45·0	101·7	180·0	14·328
16°	12·8	51·4	116·3	205·9	16·392
18°	14·4	57·9	131·0	231·9	18·456
20°	16·1	64·5	145·7	258·0	20·532

Table 52.—LENGTH OF 4-INCH PIPE TO HEAT 1000 CUBIC FEET OF AIR PER MINUTE; TEMPERATURE OF THE PIPE 200° F.

TEMPERATURE OF EXTERNAL AIR.	TEMPERATURE AT WHICH THE ROOM IS REQUIRED TO BE KEPT.									
Fahrenheit.	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
	Feet.	Feet.	Feet.	Feet	Feet.	Feet.	Feet.	Feet	Feet.	Feet.
10°	126	150	174	200	229	259	292	328	367	409
12°	119	142	166	192	220	251	283	318	357	399
14°	112	135	159	184	212	242	274	309	347	388
16°	105	127	151	176	204	233	265	300	337	378
18°	98	120	143	168	195	225	256	290	328	368
20°	91	112	135	160	187	216	247	281	318	358
22°	83	105	128	152	179	207	238	271	308	347
24°	76	97	120	144	170	199	229	262	298	337
26°	69	90	112	136	162	190	220	253	288	327
28°	61	82	104	128	154	181	211	243	279	317
30°	54	75	97	120	145	173	202	234	269	307
*32°	47	67	89	112	137	164	193	225	259	206
34°	40	60	81	104	129	155	184	215	249	286
36°	32	52	73	96	120	147	175	206	239	276
38°	25	45	66	88	112	138	166	196	230	266
40°	18	37	58	80	104	129	157	187	220	255
42°	10	30	50	72	95	121	148	178	210	245
44°	3	22	42	64	87	112	139	168	200	235
46°	...	15	34	56	79	103	130	159	190	225
48°	...	7	27	48	70	95	121	150	161	214
50°	...	...	19	40	62	86	112	140	171	204
52°	...	...	11	32	54	77	103	131	161	194

* Freezing point.

To find the length in feet of iron pipe required for heating the air in a building. *Rule:* Multiply the volume of air in cubic feet, to be warmed per minute, by the difference in temperature in the room, and the external temperature, and multiply by 1·12 for 2-inch pipes, by ·75 for 3-inch pipes. by ·56 for 4-inch pipes, and divide the product by the difference of the internal temperature and that of the pipes.

Table 53.—Length of 4-inch Pipe required to warm various Buildings.

(Divide the cubic contents of the room in feet, by one of the following divisors.)

Description of Building.	Divisor for cubic contents of Room.	Temperature Maintained.
	Feet.	Fahrenheit.
Churches and large public rooms . .	200	55°
Schools and lecture rooms	170	60°
Dwelling rooms	150	60°
Work rooms and manufactories . . .	125	60°
Halls, waiting rooms, and shops	100	60°
Leather, &c., drying rooms	40	100°
Greenhouses and conservatories	30	60°
Horticultural forcing houses	20	75°
Ditto ditto . . .	18	80°
Laundry drying rooms	8	110°

3-inch pipes require to be one-third longer than 4-inch pipes, to heat the same number of cubic feet; and 2-inch pipes require to be double the length of 4-inch pipes, to heat the same number of cubic feet.

Table 54.—Cooling of Iron Pipes.

Temperature of room, 67°; maximum temperature of thermometer, 152°.

Thermometer Cooled.		Rusty Surface.		Black Varnished Surface.		White Surface.	
From.	To.	Observed Time.	Calculated Time.	Observed Time.	Calculated Time.	Observed Time.	Calculated Time.
152°	150°	2′ 30″	2′ 21″	2′ 16″	2′ 16″	2′ 19″	2′ 24″
152°	148°	5′ 0″	4′ 40″	4′ 38″	4′ 36″	4′ 53″	4′ 51″
152°	146°	7′ 45″	7′ 12″	7′ 28″	7′ 3″	7′ 28″	7′ 22″
152°	144°	10′ 15″	9′ 44″	9′ 45″	9′ 27″	10′ 13″	9′ 57″
152°	142°	12′ 45″	12′ 15″	12′ 2″	11′ 54″	12′ 57″	12′ 36″
152°	140°	15′ 0″	15′ 0″	14′ 32″	14′ 32″	15′ 22″	15′ 22″

Table 55.—Rate of Cooling by Radiation for the same Body, at different Temperatures.

Excess of Temperature.	Velocity of Cooling when the Surrounding Medium is at the Undermentioned Temperatures.			
	0°	20°	40°	60°
220°	8·81	10·41	11·98	—
200°	7·40	8·58	10·01	11·64
180°	6·10	7·04	8·20	9·55
160°	4·89	5·67	6·61	7·68
140°	3·88	4·57	5·32	6·14
120°	3·02	3·56	4·15	4·84
100°	2·30	2·74	3·16	3·68

Table 56.—Showing the quantity of Coal used per Hour, to heat 100 feet in length of Pipe of different Sizes.

Diameter of Pipe in Inches	Difference between the Temperature of the Pipe and the Room in Degrees of Fahrenheit.														
	150	145	140	135	130	125	120	115	110	105	100	95	90	85	80
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4	4·7	4·5	4·4	4·2	4·1	3·9	3·7	3·6	3·4	3·2	3·1	2·9	2·8	2·6	2·5
3	3·8	3·4	3·3	3·1	3·0	2·9	2·8	2·7	2·5	2·4	2·3	2·2	2·1	2·0	1·8
2	2·3	2·2	2·2	2·1	2·0	1·9	1·8	1·8	1·7	1·6	1·5	1·4	1·4	1·3	1·2
1	1·1	1·1	1·1	1·0	1·0	·9	·9	·9	·8	·8	·7	·7	·7	·6	·6

When pipes are laid in trenches covered with grating the loss of heat amounts to about 10 per cent., which passes into the ground.

Boiler Power.—For heating purposes by hot water, the saddle boiler gives good results. One square foot of boiler surface exposed to the direct action of the fire, or three square feet of flue surface, will heat 40 feet of 4-inch pipe.

The Quantity of Air to be Warmed per Minute is from 4 to 5 cubic feet for each person, with the addition of 1¼ cubic feet for each square foot of glass in habitable rooms; for conservatories and hot-houses the quantity of air to be warmed is 1¼ cubic feet per square foot of glass per minute; as iron frames and sashes radiate as much heat as glass, their surfaces are to be measured with the glass. For wood frames deduct ⅓ from the gross area of surface.

Heating Rooms by Steam.—A 2 ft. 6 in. by 5 ft. Vertical boiler is sufficient for 48,000 cubic feet of space. To heat a room to 60° F. the length of steam-pipe may be found by the following rule. To find the length in feet of steam-pipe: Multiply the volume of air in cubic feet, to be warmed per minute, by the difference of temperature in the room and the external temperature, and divide the product by 304 for 4-inch pipe, or by 228 for 3-inch pipe, by 152 for 2-inch pipes, and by 76 for 1-inch pipe.

Expansion of Steam and Hot-water Pipes.—An expansion-joint should be added to long lengths of steam-pipes, to allow for their increase of length from expansion. The quantity of expansion can be found thus: Multiply the coefficient of expansion given in Table 48 by the difference in temperature of the outside and inside of the pipe, which result multiply by the length of pipe. Thus with a cast-iron steam-pipe 160 feet long, with the temperature of the air at 60° and the steam at 324° F., the difference of temperature will be 324—60 = 264°, and the increase in length due to expansion will be ·0000065 rate of expansion × 264° temperature × 160 feet × 12 inches = 3·294 inches.

VENTILATION, &c.

The Amount of Air required for the proper ventilation of apartments is from 4 to 5 cubic feet of air per head per minute in winter, and from 6 to 10 cubic feet in summer. A man makes about 17 respirations per minute each of 40 cubic inches, or $\frac{17 \times 40 \times 60}{1728} = 23{\cdot}6$ cubic feet per hour; for respiration and transpiration a man requires 215 cubic feet of air per hour. A man generates about 290 units of heat per hour, 100 units of which go in the formation of vapour, and the remaining 190 units are dissipated by radiation to the surrounding objects and contact with cold air. An ordinary gas burner consumes about 5 feet of gas per hour, and requires for combustion 12 cubic feet of air per cubic foot of gas, or 60 cubic feet per hour for each gas burner; each cubic foot of gas burned emits about 690 units of heat; each pound of candles or oil burnt requires 160 cubic feet of air for combustion, and emits 16,000 units of heat.

The Quantity of Air required for the proper ventilation of various buildings is given below :—

	Cubic feet per head per hour.
For apartments with healthy occupants	300
For apartments with sick occupants	1200
For prisons and workhouses	350
For churches and assembly rooms	550
Hospitals, ordinary, and barracks	2200
Hospitals for infectious diseases	4500

The Space provided for each Bed in the wards of ordinary hospitals, should not be less than 1800 cubit feet, and in hospitals for infectious diseases not less than 2500 cubic feet. The space provided in dwelling houses, should not be less than 300 cubic feet for each person in a room, whether children or adults, as children require as much space as adults.

Ventilation of Mines.—The quantity of air required for the health of each person underground is 100 cubic feet per minute; in addition to this, in fiery mines air is required in the proportion of 30 cubic feet for each cubic foot per minute of firedamp given off.

Space Required for Animals.—A pig requires 10 square feet of floor space; a sheep, 15; a bullock, 70; a cow, 100; and a horse, 120 square feet of floor space. The cubical space should equal 13 times the given floor space for a horse, and 10 times the given floor space for each of the other animals above mentioned.

Furnace-ventilation.—The power obtained is measured by the difference between the weights of air in the downcast and upcast shafts. The length of column in the downcast shaft, which would be equal in weight to the difference of the weight of air in the two shafts, is called the motive column. To find the motive column.—*Rule:* From the temperature of the upcast shaft, subtract the temperature of the downcast shaft, and divide the remainder by the product of the temperature of the upcast multiplied by 459; multiply this quotient by the depth in feet of the downcast shaft.

To find the weight in lbs. of a cubic foot of air.—Divide the number 519 by the product of 459 multiplied by the temperature, and multiply the quotient by ·0765546. By multiplying the weight of one cubic foot of the air in the shaft by the cubic area of the shaft, the total weight of the air in the shaft is obtained.

Weight of one cubic foot of pure Air under a pressure of one atmosphere.

				lbs.					lbs.
At	0°	Fahr.	=	·0866	At	300°	Fahr.	=	·0525
,,	12°	,,	=	·0845	,,	400°	,,	=	·0465
,,	22°	,,	=	·0826	,,	500°	,,	=	·0415
,,	32°	,,	=	·0808	,,	800°	,,	=	·0318
,,	62°	,,	=	·0762	,,	1200°	,,	=	·0242
,,	102°	,,	=	·0709	,,	2000°	,,	=	·0165
,,	162°	,,	=	·0640	,,	2500°	,,	=	·0136
,,	212°	,,	=	·0592	"	3000°	,,	=	·0116

Atmospheric Air is increased in volume by elevation of temperature, as follows.

At	32°	Fahr.,	volume	=	1·000	At	180°	Fahr.,	volume	=	1·310
,,	42°	,,	,,	=	1·021	,,	212°	,,	,,	=	1·370
,,	50°	,,	,,	=	1·040	,,	300°	,,	,,	=	1·550
,,	60°	,,	,,	=	1·060	,,	400°	,,	,,	=	1·756
,,	70°	,,	,,	=	1·080	,,	500°	,,	,,	=	1·960
,,	80°	,,	,,	=	1·100	,,	800°	,,	,,	=	2·570
,,	90°	,,	,,	=	1·120	,,	1200°	,,	,,	=	3·386
,,	100°	,,	,,	=	1·140	,,	1600°	,,	,,	=	4·200
,,	120°	,,	,,	=	1·180	,,	2000°	,,	,,	=	5·020
,,	150°	,,	,,	=	1·242	,,	3000°	,,	,,	=	7·058

Heating Water in Tanks by Steam.—In heating water by blowing steam into it through a perforated pipe placed at the bottom of a tank, the quantity of steam required is, approximately, 1 lb. for every 5 lbs. of water heated to 212° Fahr. The exact quantity may be calculated as follows:—

Suppose 200 gallons of water at a temperature of 52° Fahr. are to be heated to the boiling point, 212° Fahr., by steam of 60 lbs. per square inch pressure by the steam-gauge. Then to heat 1 lb. of water from 52° to 212° Fahr. requires 212° − 52° = 160 units of heat, and the total heat required is = 200 gallons × 10 lbs. = 2,000 lbs. × 160 units = 320,000 units. The total heat of steam of 60 lbs. + 15 lbs. = 75 lbs. per square inch absolute pressure, is, from Table 1, page 16 = 1,185·2° Fahr.; and 1,185·2° − 212° = 973·2 heat units are available per lb. of water. Then 320,000 units ÷ 973·2 units = 328·6 lbs. of steam are required to heat the water.

According to the above approximate rule, to heat this quantity of water, 2,000 lbs. of water ÷ 5 = 400 lbs. of steam are necessary, or about 25 per cent. more than the quantity actually required.

Condensation of Steam in Pipes Cooled by Water.—In some experiments with surface condensers, in which the steam was passed through the tubes, 500 units of heat by condensation were transmitted per square foot of tube-surface per hour per 1° Fahr. difference of temperature. The condensers were arranged in three groups of tubes, successively traversed by the condensing water. In another case, where the condenser was arranged in two groups, from 220 to 240 units were transmitted.

Experiments have been made with an ordinary surface-condenser brass tube, ¾ inch external diameter and 18-wire gauge in thickness, encased in a 3¾ inch diameter iron pipe. Steam of 32½ lbs. total pressure per square inch occupied the inter-space, and cold water at 58° Fahr. flowed through the brass tube. Three experiments were made with the tube in a vertical position, and also in a horizontal position, the results of which were as follows:—

	Vertical position.			Horizontal position.		
	1	2	3	4	5	6
Velocity of water through the tube in feet per minute:—	81	278	390	78	307	415 feet.
Steam condensed per square foot of surface per hour for 1° Fahr. difference of temperature:—	·335	·436	·457	·480	·603	·699 lb.
Heat absorbed by the water per square foot per hour for 1° Fahr. difference of temperature:—	346	449	466	479	621	696 units.

The rate of condensation was greater in the horizontal position than in the vertical position. Also, the efficiency of the condensing surface was increased by an increase of velocity of the water through the tube, nearly in the ratio of the fourth root of the velocity for vertical tubes; and nearly as the 4·5 root for horizontal tubes.

Comparative Rate of Emission of Heat from Pipes.—The rate of emission of heat from pipes varies considerably. For equal total difference of temperature the rate of emission of heat from steam-pipes placed in water, is from 150 to 250 times as great as the rate when they are placed in air, according as the pipes are in a vertical or horizontal position.

The rate of emission of heat from water-tubes placed in water is about 20 times as great as the rate when they are placed in air. In one experiment it was proved to be 25 times. When the water-tube was moved through the air at a speed of 59 feet per second, it was cooled in one-twelfth of the time occupied in still air. In water moved at a speed of 3 feet per second, the water in the tube was cooled in one-half the time.

Refrigerating Machinery.—For the cooling of brine and other liquids by the alternate compression and expansion of air, the following formulæ has been evolved in which the machine is supposed to be perfect:—

$$P = 772\, C \times \frac{T - t}{T}; \quad C = \frac{P}{772} \times \frac{T}{T - t}.$$

In which P = the power required to do the cooling work C, in foot-pounds.
C = the cooling work done, in thermal units.
T = the absolute maximum temperature in degrees Fahr. of the air in the hot or compression-end of the machine.
t = the absolute minimum temperature in degrees Fahr. of the air in the cold or expansion-end of the machine.

These formulæ indicate that the most economical results, as regards consumption of power, are obtained when the machine is worked within a small range of temperature, as in breweries, where the temperature of the water has frequently to be lowered only 10° Fahr.

These formulæ are applicable to all cooling machines, whether they operate by means of air, ether, ammonia, or any other fluid.

In the ammonia machine, or other machine working on the same principle, in which no mechanical power is applied, the value of P, it is understood, is the heat theoretically required, at the rate of 1 heat-unit for 772 foot-pounds of power; and the first formula given above becomes:—

(Ammonia) Heat required to do the work $C = (T - t) \div t$.

The ammonia machine has, theoretically, a great economical superiority, as heat is so much less expensive than its equivalent of mechanical power.

The nature of the vapour employed influences the size of the machine, as will be seen from the following table:—

Table 57.—RELATIVE CAPACITY OF CYLINDER FOR DIFFERENT VAPOURS.

Ammonia	1·00	Methyl Ether	1·8
Carbonic Acid	0·16	Sulphurous Acid	2·6
Methyl Chloride	1·80	Ether	15·1

CUTTING METALS.

The most advantageous speed in lineal feet per minute, for planing, shaping, slotting, and turning metals, is, for copper 120 feet, brass 50 feet, wrought-iron 20 feet, cast-iron 18 feet, steel 12 feet. By dividing these numbers by the circumference in feet of the work to be turned, the number of revolutions of the lathe-spindle is obtained. For boring work in a lathe, the speed is limited by the overhanging of the tool, to from 6 to 10 feet per minute; for screwing bolts and tapping nuts the surface-speed is from 4 to 8 feet per minute. The speed of cutters for wheel-cutting and milling machines should not exceed 18 feet per minute at the largest cutting diameter. The use of high speed steel tools will allow the cutting speeds to be increased from 50 per cent. to 150 per cent.

Table 58.—CUTTING SPEEDS FOR LATHE WORK.

Diameter of the Work in Inches.	WROUGHT IRON.	CAST IRON.	STEEL.	BRASS.	COPPER.
	Number of Revolutions per Minute of the Lathe Spindle.	Number of Revolutions per Minute of the Lathe Spindle.	Number of Revolutions per Minute of the Lathe Spindle.	Number of Revolutions per Minute of the Lathe Spindle.	Number of Revolutions per Minute of the Lathe Spindle.
1	76	68	45	190	456
1½	50	45	30	127	300
2	38	34	22	95	228
2½	30	27	18	75	180
3	25	22	15	63	150
3½	22	19	13	55	132
4	19	17	11	47	114
5	15	13	9	38	90
6	12	11	7·6	30	72
7	10	9	6·5	25	60
8	9	8·6	5·7	23	54
10	7·7	6·8	4·58	19	46
12	6·3	5·7	3·83	16	37
15	5·0	4·5	3·05		
18	4·24	3·8	2·54		
21	3·63	3·27	2·18		
24	3·18	2·85	1·91		
30	2·54	2·29	1·52		
36	2·12	1·91	1·27		
42	1·81	1·66	1·10		
48	1·59	1·44	·96		
54	1·41	1·27	·85		
60	1·27	1·14	·76		
72	1·06	·95	·63		
84	·90	·82	·54		
96	·79	·71	·47		
108	·70	·63	·44		

NOTE.—With strong special machine tools, and special tool-steel, the cutting speeds may be five or six times as great as those given on this and the next page.

The speed for turning chilled rolls is from 3 to 4 feet per minute. The speed for cutting screws is equal to two-thirds of the speed for turning metals.

Table 59.—Speed in Revolutions per Minute of Plain Drills and Twist Drills for Drilling various Metals.

Diameter of Drill in inches.	Steel.	Cast Iron.	Wrought Iron.	Bronze and Gun-metal.	Brass.	Aluminium.	Copper.
Plain Drill.	Rev.	Rev.	Rev.	Rev.	Rev.	Rev.	Rev.
$\frac{1}{16}$	770	1000	1300	1400	1500	1900	3600
$\frac{1}{8}$	430	570	720	800	880	1100	2200
$\frac{1}{4}$	190	250	320	460	600	750	1440
$\frac{3}{8}$	145	190	240	320	400	500	960
$\frac{1}{2}$	95	130	160	220	280	350	670
$\frac{5}{8}$	80	110	135	180	225	280	540
$\frac{3}{4}$	60	75	95	160	160	200	380
$\frac{7}{8}$	50	65	80	110	130	165	310
1	45	55	70	90	110	140	260
Twist Drill.							
$\frac{1}{16}$	960	1280	1600	1750	1900	2380	4500
$\frac{1}{8}$	540	720	900	1000	1100	1380	2640
$\frac{3}{16}$	360	480	600	720	850	1060	2040
$\frac{1}{4}$	240	320	400	570	750	940	1800
$\frac{3}{8}$	180	240	300	400	500	630	1200
$\frac{1}{2}$	120	160	200	270	350	440	840
$\frac{5}{8}$	100	135	170	220	280	350	670
$\frac{3}{4}$	75	95	120	160	200	250	480
$\frac{7}{8}$	60	80	100	130	160	210	380
1	55	70	85	110	140	180	340
$1\frac{1}{8}$	50	60	75	100	120	160	290
$1\frac{1}{4}$	45	52	65	90	110	140	260
$1\frac{3}{8}$	40	48	60	80	100	130	240
$1\frac{1}{2}$	35	44	55	70	90	115	220
$1\frac{5}{8}$	33	40	50	65	80	100	190
$1\frac{3}{4}$	30	36	45	60	70	95	170
$1\frac{7}{8}$	28	34	42	50	60	75	140
2	25	32	40	45	50	65	120
$2\frac{1}{2}$	18	24	30	33	35	45	85
3	16	22	28	31	33	42	80
$3\frac{1}{2}$	14	20	24	26	28	35	75
4	12	16	20	22	24	30	60

The rate of the feed of a drill should be in proportion to the hardness of the metal. In drilling wrought iron, the number of revolutions of the drill per inch of feed may generally be 300 for drills of $\frac{1}{16}$, $\frac{1}{8}$, and $\frac{3}{16}$ inch diameter; 200 for a drill of $\frac{1}{4}$ inch diameter; 150 for drills of $\frac{5}{16}$, $\frac{3}{8}$, and $\frac{7}{16}$ inch diameter, and 100 for drills of from $\frac{1}{2}$ inch to 4 inches diameter.

The feed or advance of tool suitable for the speeds given in the table of cutting speeds for lathe work, is given in the following table for roughing cuts. The finishing cut should be as light as possible, with a broad advance or feed of cut.

Table 60.—FEED OR ADVANCE OF CUT FOR ROUGHING CUTS IN LATHE WORK.

Diameter of Work, in Inches.	ADVANCE OR TRAVEL OF THE TOOL TO ONE REVOLUTION OF THE LATHE SPINDLE.				
	Wrought-Iron.	Cast Iron.	Steel.	Brass.	Copper.
	Inch.	Inch.	Inch.	Inch.	Inch.
Under $1\frac{1}{4}$ inches .	$\frac{1}{32}$	$\frac{1}{24}$	$\frac{1}{40}$	$\frac{1}{24}$	$\frac{1}{24}$
$1\frac{1}{4}$ to 2 " .	$\frac{1}{24}$	$\frac{1}{20}$	$\frac{1}{32}$	$\frac{1}{24}$	$\frac{1}{24}$
$2\frac{1}{8}$ to $2\frac{7}{8}$ " .	$\frac{1}{20}$	$\frac{1}{18}$	$\frac{1}{24}$	$\frac{1}{24}$	$\frac{1}{24}$
3 to $5\frac{7}{8}$ " .	$\frac{1}{16}$	$\frac{1}{14}$	$\frac{1}{20}$	$\frac{1}{24}$	$\frac{1}{24}$
6 to 12 " .	$\frac{1}{10}$	$\frac{1}{8}$	$\frac{1}{18}$	$\frac{1}{24}$	$\frac{1}{24}$
13 and upwards .	$\frac{1}{8}$	$\frac{1}{7}$	$\frac{1}{16}$	$\frac{1}{24}$	$\frac{1}{24}$

As each revolution of the lathe moves the tool forward the portion of an inch given in this table, a 3-inch shaft making 25 revolutions per minute would be turned with a rough cut at the rate of $\frac{25 \text{ revolutions}}{16 \text{ advance}} = 1\frac{9}{16}$ inch in length per minute.

The feed or advance of the tool of a planing machine should be 14 or 12 cuts per inch for roughing cuts, and the finishing cuts should be done with a broad tool having an advance for each cut of from $\frac{1}{4}$ to $\frac{3}{8}$ inch.

Speed of circular saws for cutting metal, for brass 350 lineal feet per minute, for cast-iron 190 feet per minute, for wrought-iron 150 lineal feet per minute.

The speed per square foot of surface at which metals can be cut, depends greatly upon the efficiency and rigidity of the machine tools, as well as upon the softness and quality of the metal; some iron is very scaly and dirty, and soon blunts the tool. In the following table is given the time required to finish work, including one roughing cut and one finishing cut, the average of a great quantity of work done by ordinary good tools: the finishing cut being light with a broad advance.

Lathe Centres.—The usual angle for lathe centres is 60°; but for heavy work a more durable angle is 75°. For heavy work the centre should have a small hole bored up its centre, and another hole drilled at right angles to meet it, by which means the bearing surfaces can be properly oiled without stopping the lathe.

Cutting Angle of Lathe Tools.—The cutting angle best adapted for turning tools for soft wood is 30°, for hard wood 40°, for wrought-iron and steel 60°, for cast-iron 70°, for brass 80°, for very hard metals 84°, for gun metal 85°, for hard brass and hard gun metal 90°, and for chilled rolls 90°. The angle of clearance of these tools varies from 3° to 7°.

Table 61.—WORK DONE BY PLANING, SHAPING, SLOTTING, DRILLING, AND BORING MACHINES AND LATHES.

Description of Work.			Time required for 2 Cuts, viz., 1 Roughing and 1 Finishing Cut, to Finish 1 Square Foot.	
	ft.	in.	Hrs.	Min.
Planing cast iron work	1	6 long	1	0
Ditto ditto	2	6 ,,	0	40
Ditto ditto	4	0 ,,	0	35
Ditto ditto	5	0 ,,	0	30
Ditto ditto	8	0 ,,	0	25
Ditto ditto	16	0 ,,	0	20
Shaping cast iron work	0	3 ,,	3	0
Ditto ditto	0	4 ,,	2	30
Ditto ditto	0	6 ,,	2	0
Ditto ditto	0	9 ,,	1	50
Ditto ditto	1	0 ,,	1	40
Ditto ditto	1	3 ,,	1	25
Ditto ditto	1	8 ,,	1	10
Slotting cast iron work	0	3 deep	3	30
Ditto ditto	0	4 ,,	3	0
Ditto ditto	0	6 ,,	2	30
Ditto ditto	0	9 ,,	2	15
Ditto ditto	1	0 ,,	2	0
Ditto ditto	1	3 ,,	1	50
Ditto ditto	1	6 ,,	1	40
Slot drilling keyway, 6 inches long × ¾ × ⅜ inch			0	40
Ditto ditto 9 ditto × 1 × 1½ inch			1	0
Planing keyway, 4 feet long × ¾ inch wide × ⅜ inch deep			2	0
Screwing machine, screwing ½ inch iron, 1 foot long			0	3
Screwing 1 inch iron, 1 foot long			0	4
Tapping 1 gross ½ inch nuts			0	30
Tapping 1 gross 1 inch nnts			1	0
Drilling 1 inch diameter holes in cast-iron, per square foot			1	30

Description of Work.	Time required for 2 Cuts, viz., 1 Roughing and 1 Finishing Cut.	
	Hrs.	Min.
Boring 6 inch diameter holes in cast iron, per square foot	1	0
Turning 1 ft. length of wrought iron shaft, 1 in. diameter	0	13
Ditto ditto ditto 1½ ,,	0	14
Ditto ditto ditto 2 ,,	0	17
Ditto ditto ditto 2½ ,,	0	18
Ditto ditto ditto 3 ,,	0	20
Ditto ditto ditto 3½ ,,	0	22
Ditto ditto ditto 4 ,,	0	25
Ditto ditto ditto 5 ,,	0	28
Ditto ditto ditto 6 ,,	0	30
Ditto ditto ditto 7 ,,	0	32
Ditto ditto ditto 8 ,,	0	35
Ditto ditto ditto 9 ,,	0	40
Ditto ditto ditto 10 ,,	0	45
Ditto ditto ditto 11 ,,	0	52
Ditto ditto ditto 12 ,,	1	0
Turning 1 foot in length of round steel, 2 inch diameter	0	25
Turning 1 foot in length of round brass, 2 inch diameter	0	10
Surfacing a flat cast-iron plate, per square foot	0	16
Surfacing a flat wrought-iron plate, per square foot	0	12
Surfacing a flat steel plate, per square foot	0	20
Surfacing a flat brass plate, per square foot	0	10
Turning pulleys from 2 to 4 feet diameter, per square foot	0	25
Turning pulleys from 5 to 8 feet diameter, per square foot	0	20
Turning small fly-wheels from 3 to 6 feet diameter, per square foot	0	15
Turning fly-wheels from 7 to 12 ft. diameter, per square foot	0	12
Turning hard cast iron rolls, per square foot	1	0

NOTE.—The time given includes the time occupied in setting the work. The lathes for turning pulleys and fly-wheels had several tools cutting at one and the same time. The time given above is for work done by ordinary machine tools with ordinary tool-steel. With strong special machine-tools and special tool-steel, some of the work may be done in less than one-half the time given in this Table.

CUTTING METALS AT A HIGH SPEED.

Water-Cooled Carbon Tool Steel.—The speeds for cutting metals given on the preceding pages are suitable for ordinary machine tools of ordinary weight and strength, when using ordinary water-cooled carbon tool steel.

Oil-Cooled Carbon Tool Steel.—With extra strong and very stiff machine tools, when using tools of hard oil-cooled carbon tool steel, soft cast-iron, soft wrought-iron, and soft mild steel may be turned, planed, shaped, slotted, and milled at speeds of from 25 to 28 feet per minute, and drilled at speeds of from 30 to 40 feet per minute.

Suitable Speeds and Feeds for Twist Drills of hard oil-cooled carbon tool steel are given in the following table, in which the cutting speeds of drills of from $\frac{1}{8}$ to 1 inch diameter is 40 feet per minute; of drills of from $1\frac{1}{8}$ to 2 inches diameter it is 35 feet per minute; and of drills of from $2\frac{1}{4}$ to 4 inches diameter it is 30 feet per minute.

Table 61A.—Speeds and Feeds of Twist Drills of Hard Oil-Cooled Carbon Tool Steel.

Diameter of the Drill Inches.	Revolutions of the Drill per Minute	Feed per Revolution Inch	Diameter of the Drill Inches	Revolutions of the Drill per Minute	Feed per Revolution Inch
$\frac{1}{8}$	1232	·006	$1\frac{3}{8}$	98	·015
$\frac{3}{16}$	816	·006	$1\frac{1}{2}$	90	·015
$\frac{1}{4}$	616	·006	$1\frac{5}{8}$	83	·015
$\frac{5}{16}$	490	·006	$1\frac{3}{4}$	78	·015
$\frac{3}{8}$	408	·008	$1\frac{7}{8}$	72	·015
$\frac{7}{16}$	350	·008	2	63	·015
$\frac{1}{2}$	308	·011	$2\frac{1}{4}$	52	·018
$\frac{9}{16}$	273	·011	$2\frac{1}{2}$	49	·018
$\frac{5}{8}$	246	·011	$2\frac{3}{4}$	42	·018
$\frac{3}{4}$	204	·011	3	38	·018
$\frac{7}{8}$	175	·011	$3\frac{1}{4}$	36	·018
1	154	·015	$3\frac{1}{2}$	32	·020
$1\frac{1}{8}$	144	·015	$3\frac{3}{4}$	30	·020
$1\frac{1}{4}$	108	·015	4	28	·020

A Round Fluted Drill is better than a twist drill for boring a long hole in work which revolves in a lathe and the drill is stationary. It has two straight deep opposite flutes, and is fixed in a holder of less diameter than the drill. The lubricant is supplied under pressure through a pipe placed in one of the flutes when boring iron or steel.

Machining Metals.—Precision is of great importance in machining metals. To obtain efficiency and prevent injury to a metal it should be cut with a sharp tool of the correct size and shape, both for the particular work and for making a clean cut; and its cutting speed should be suitable for the hardness of the metal. The harder the metal, or the heavier the cut, the slower should be the cutting speed. The softer the metal, or the lighter the cut, the higher should be the cutting speed.

Gun metal may be machined at a 50 per cent. higher speed and brass at double the speed given on the preceding page for other metals. To be easily cut these alloys should contain lead. A gun metal that will both cast well and machine well is composed of copper, 85; tin, 5; zinc, 5; lead, 5 per cent.

The machining of metal at a high speed is economical and advantageous because it comprises a large output of work. The quantity of work produced by a machine tool, however, partly depends upon the degree of expert skill of its minder.

Cutting Speed Calculations.—When machine tools are working, the speed in feet per minute at which they are cutting metals is as follows:—With lathes and turning mills it is = (the diameter of the work in feet) × 3·1416 × (the number of revolutions per minute of the work). With shaping machines, slotting machines, and planing machines, it is = (the length in inches of the cutting stroke × 5) ÷ (the time in seconds of the cutting stroke).

With drilling machines, boring machines, and milling machines it is = (the diameter in feet of the drill or cutter) × 3·1416 × (the number of revolutions per minute).

The time occupied in cutting metal may be calculated as follows:—Take the case of a shaft 6 inches diameter being turned at a speed of 80 feet per minute with a feed of $\frac{1}{16}$th inch per revolution. Then 6 inches ÷ 12 inches = ·5 foot × 3·1416 = 1·57 foot circumference, and 80 feet ÷ 1·57 = 51 revolutions per minute, and 51 ÷ 16 the feed = 3·19 inches the length cut per minute. Then the time occupied in turning one foot in length of the shaft is = 12 inches ÷ 3·19 = 3·75 minutes.

For the properties of numerous metals, see pages 240—244, 355—360. For processes for hardening, softening, and tempering metals, see pages 264—270.

The Deep Cutting of Metals.—When cutting metals with a machine tool, the depth of the cut and the rate of the feed of the cutting tool should be suitable for the nature of the metal. Very deep cuts and heavy feeds are liable to considerably strain and tear the metal and start incipient cracks which may develop into flaws under the continual heavy working strain of the machine or engine of which it will be a part, and cause a breakdown. As a crank axle is subject to the great severity of continuity of repeated alternate stresses of tension and compression, it should therefore be forged so near its finished size that deep cutting is avoided.

Weight of Metal Cuttings.—The weight in pounds of the cuttings of metals is equal to the product of their bulk in cubic inches multiplied by the weight of a cubic inch of the metal. To find the weight in pounds of metal cut off with a lathe when turning a shaft

Let D = the diameter in inches of the shaft before being turned.
d = its diameter in inches after being turned.
L = the length in inches turned.
C = the weight per lb. of a cubic inch of the metal.

Then $[(D^2 \times \cdot7854 \times L) - (d^2 \times \cdot7854 \times L)] \times C$.

To find the weight in lbs. of borings in drilling a hole in metal—

Let D = the diameter in inches of the drilled hole.
d = its depth in inches.
C = The weight per lb. of a cubic inch of the metal.

Then $(D^2 \times \cdot7854 \times d) \times C$.

To find the weight of metal in lbs. cut per minute by shaping machines, slotting machines, and planing machines—

Let L = the length in inches cut at each stroke of the machine.
N = the number of the strokes per minute cutting the metal.
D = The depth in inches of the cut.
W = the width in inches of the cut.
C = the weight per lb. of a cubic inch of the metal.

Then $L \times N \times D \times W \times C$.

For milling machines L is equal to the length in inches traversed by the table of the machine per minute.

Then taking the above notation, the weight of metal cut in lbs. per minute is $= L \times W \times D \times C$.

The weight of a cubic inch of various metals is given in Table 99, on page 296, which is, however, only approximate, because the specific gravity of a metal varies according to its degree of purity.

Tungsten Tool Steel for Cutting Metals at a High Speed.—This steel is air-cooled and self-hardening. It has great power of endurance and very great strength, which enable it to make heavy cuts very rapidly. It will also withstand the high temperature generally produced by the friction of the tool on the metal when cutting it rapidly. The temperature of this friction may be as high as 1200° Fahr. without the tool sensibly losing its hardness and cutting power. If the working temperature of the tool should even become as high as to cause its point to become red-hot, it will cut for a considerable time without breaking down.

It has been proved that the use of High Speed Steel when cutting at high speeds is economical in mechanical efficiency, and that a given horse-power will remove a greater quantity of metal at a high speed than at a low speed, and that the horse-power absorbed for each lb. of metal cut is less when cut at a high speed than at a low speed.

Superior High Speed Tool Steel composed of an alloy of tungsten, chromium, and other metals, is made by Sir W. G. Armstrong, Whitworth & Co., Limited, Openshaw, Manchester, which is termed the AW special brand. Steel may be cut with it at any speed up to 500 feet per minute. It has very remarkable cutting power, very high productive power, and very great durability, consequently tools made of it cut a considerable time without regrinding.

To cut metal efficiently at a high speed very powerful and massive machine tools are necessary. They permit, when using AW special tool steel, metals to be very rapidly turned, planed, shaped, slotted, milled, and drilled; and they very readily effect the production of the maximum quantity of work at the minimum cost.

Cutting Metals with High Speed Tool Steel.—Metals may be efficiently cut with a tool of AW steel at the following speeds, which vary considerably because they must accord with the depth and width of the cut, the hardness of the metal, and the capacity of the particular machine tool for doing its work well.

Experience proves that soft cast-iron, soft wrought-iron, and soft mild steel may be efficiently cut at the following speeds :—

	Cutting Speed in Feet per Minute.
Screwed and tapped at	15— 75
Shaped and slotted at	25— 80
Planed at	40—100
Turned at	50—240
Drilled and milled at	60—250
Polished in a lathe at	100—260
Bronze, gun metal, brass, and copper may be turned and otherwise machined at	100—300
Hard cast-iron, hard forged steel, and hard steel castings may be turned and otherwise machined at . . .	10— 80
Chilled cast-iron rolls may be turned at	8— 12

Cast-iron, wrought-iron, steel and other metals may be sawn at a speed of from 20—130 feet per minute with a machine tool having one or more circular saws fitted with renewable teeth of AW steel.

Depth of Cut and Feed of the Tools of High Speed Lathes.—When lathes are cutting with tools of AW steel, soft cast iron, soft wrought-iron and soft mild steel, cuts of $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$, and 1 inch deep are frequently made and the feed or traverse of the tool per revolution of the work varies

	Feet per Minute
From $\frac{1}{16}$—$\frac{5}{16}$ inch for a cutting speed of . .	25— 60
,, $\frac{1}{16}$—$\frac{1}{4}$ inch ,, ,, . . .	70—120
,, $\frac{1}{16}$—$\frac{3}{16}$ inch ,, ,, . .	130—180
,, $\frac{1}{32}$—$\frac{1}{8}$ inch ,, ,, . . .	190—240

For hard cast-iron and hard steel the depth of the cut is frequently from $\frac{1}{8}$ to $\frac{3}{8}$ inch, and the feed of the tool is from $\frac{1}{32}$ to $\frac{1}{8}$ inch.

The depth of the cut and the feed of high speed planing, shaping, slotting, and milling machines are frequently the same as given above for high speed lathes.

The Actual or Brake Horse Power required to drive Machine Tools for Cutting Metals varies according to the Speed, the Depth of the Cut, and the Rate of the Feed. For High Speed Heavy Duty Machine Tools it is sometimes as follows :

For Planing Machines with Two Tool-Boxes—

Size of Machine . .	4×4×15	5×5×18	6×6×20 Feet.
The Horse-Power is .	22	28	35

For Shaping Machines of	10	12	16	20	24	Inches Stroke.
The Horse-Power is .	3	4	5	6	7	
For Slotting Machines of	10	12	16	20	24	Inches Stroke.
The Horse-Power is .	4	6	9	12	16	

When a Lathe is Turning Heavy Work, a considerable portion of the power is used in making the work revolve, and the Indicated Horse Power required to drive High Speed Heavy Duty Lathes is sometimes as follows :—

Height of Centre of the Lathe	13	16	18	24	30	Inches.
The Horse-Power is . .	20	25	30	35	45	

The Power required to drive Light Duty Lathes is given on page 350.

Drilling Metals at a High Speed.—The ordinary grade of mild steel and soft cast-iron may be drilled at the following speeds :—

Table 61B.—SPEEDS AND FEEDS RECOMMENDED FOR TWIST DRILLS OF AW HIGH SPEED STEEL.

Diameter of Drill		Revolutions per Minute	Feed in Inches per Revolution	Feed in Inches per Minute
M/m	Inches			
6	$\frac{1}{4}$	1400	·0072	10·1
8	$\frac{5}{16}$	1120	·0078	8·75
10	$\frac{3}{8}$	935	·0083	7·75
11	$\frac{7}{16}$	800	·0087	6·96
13	$\frac{1}{2}$	690	·0091	6·30
14	$\frac{9}{16}$	613	·0095	5·85
16	$\frac{5}{8}$	550	·0098	5·40
17	$\frac{11}{16}$	498	·0101	5·05
19	$\frac{3}{4}$	455	·0104	4·73
21	$\frac{13}{16}$	418	·0107	4·47
22	$\frac{7}{8}$	386	·0110	4·25
24	$\frac{15}{16}$	360	·0112	4·03
25	1	336	·0114	3·83
28	$1\frac{1}{8}$	295	·0119	3·51
32	$1\frac{1}{4}$	264	·0123	3·25
35	$1\frac{3}{8}$	238	·0127	3·02
38	$1\frac{1}{2}$	216	·0131	2·83
41	$1\frac{5}{8}$	197	·0135	2·66
44	$1\frac{3}{4}$	180	·0138	2·48
48	$1\frac{7}{8}$	168	·0141	2·37
51	2	155	·0144	2·23
54	$2\frac{1}{8}$	145	·0146	2·12
57	$2\frac{1}{4}$	135	·0150	2·03
60	$2\frac{3}{8}$	128	·0152	1·94
64	$2\frac{1}{2}$	120	·0155	1·85
67	$2\frac{5}{8}$	113	·0157	1·77
70	$2\frac{3}{4}$	107	·0160	1·71
73	$2\frac{7}{8}$	102	·0163	1·66
76	3	96	·0165	1·58

For drilling brass the speeds may be increased 100 per cent.

Feeds for cast-iron may be increased 25 per cent. for all drills of $\frac{3}{4}$ inch diameter and larger. When drilling steel maintain an efficient supply of lubrication. When drilling hard materials or deep holes reduce the speed and the feed accordingly. Grind the drills by a machine, wet, if possible, using gentle pressure. Don't force.

Cutting Metals with Emery Wheels.—Metals may be efficiently cut with an emery wheel in a grinding machine. The surface speeds given in the following table are frequently used for external grinding. For internal grinding, or grinding holes, the surface speeds used are frequently from one-fourth to one-half of those for external grinding.

The velocity rules of emery wheels are as follows :—

Let D = the diameter in inches of the emery wheel.
S = the circumferential or surface speed in feet per minute of the emery wheel.
R = the number of revolutions per minute of the emery wheel.

Then $S = (D \times 3{\cdot}1416 \times R) \div 12$ inches.
$R = (S \times 12 \text{ inches}) \div (D \times 3{\cdot}1416)$.

The traverse of the table of the machine is frequently from 15 to 50 feet per minute for external grinding, and from 5 to 15 feet per minute for internal grinding. The work speed is from 10 to 40 feet per minute.

Table 61c.—Number of Revolutions per Minute of Emery Wheels.

Diameter of the Emery Wheel in Inches	Surface Speed in Feet per Minute of the Emery Wheel				
	4000	4500	5000	5500	6000
	Number of Revolutions per Minute of the Emery Wheel				
1	15278	17188	19098	21008	22918
2	7639	8594	9549	10504	11459
3	5092	5729	6366	7002	7639
4	3819	4299	4774	5252	5729
5	3055	3437	3819	4201	4583
6	2546	2864	3183	3501	3819
7	2182	2455	2728	3001	3274
8	1909	2148	2387	2626	2864
9	1697	1910	2122	2334	2546
10	1527	1718	1909	2100	2291
12	1272	1432	1591	1750	1909
14	1091	1227	1364	1500	1637
16	954	1074	1193	1313	1432
18	848	955	1061	1167	1273
20	763	859	954	1050	1145
22	694	781	868	954	1041
24	636	716	795	875	954
26	587	661	735	808	881
28	545	613	682	750	818
30	509	573	636	700	763

Metal Work intended to be artistically ornamental should be designed with a keen perception of beauty. It should reflect so many beautiful artistic conceptions as to be a thing of beauty.

In Machine Design art and science should be combined with great mechanical skill. For lack of expert knowledge in mechanics and mechanism, many imperfect mechanical motions and devices have been produced.

SPEED FOR WOOD-WORKING MACHINERY, &c.

Table 62.—Speed for Circular Saws.

Diameter of Saw.	Number of Revolutions per Minute.	Diameter of Saw.	Number of Revolutions per Minute.	Diameter of Saw.	Number of Revolutions per Minute	Diameter of Saw.	Number of Revolutions per Minute.
Inches.		Inches.		Inches.		Inches.	
10	3500	24	1500	38	920	54	600
12	3000	26	1300	40	870	56	580
14	2500	28	1200	42	830	58	560
16	2200	30	1150	44	800	60	540
18	2000	32	1100	48	700	62	520
20	1800	34	1050	50	670	64	500
22	1600	36	1000	52	640	66	480

Table 63.—Speed and Approximate Indicated Horse-Power required to drive Wood-working Machinery, with an Average Rate of Feed.

Description of Wood-Working Machinery.	Number of Revolutions per Minute.	Indicated Horse-Power required to drive it.
Circular saw bench. Size of saw, 14 in. diameter	2500	3
Ditto ditto 24 ,,	1500	6
Ditto ditto 30 ,,	1150	10
Ditto ditto 36 ,,	1000	15
Ditto ditto 42 ,,	830	20
Ditto ditto 48 ,,	700	25
Band saw. Diameter of saw pulleys, 24 inches .	500	$1\frac{1}{2}$
Ditto ditto 30 ,,	450	2
Ditto ditto 36 ,,	400	4
Ditto ditto 42 ,,	350	6
Vertical timber frame to saw 12 in. logs. Speed of crank shaft	180	8
Ditto ditto 18 ditto ,,	160	12
Ditto ditto 24 ditto ,,	140	15
Ditto ditto 30 ditto ,,	130	20
Double deal frame for deals 11 × 3 in. ,,	400	8
Ditto ditto 14 × 4 ,, ,,	350	9
Ditto ditto 18 × 4 ,, ,,	300	12
Single deal frame for deals 11 × 3 ,, ,,	400	5
Ditto ditto 14 × 4 ,, ,,	350	6
General joiner	1500	15
Boring, chamfering, and shaping machine. Speed	4000	6
Planing and moulding machine	5000	12
Rate of feed for planing and moulding machine, 20 to 30 feet per minute.		
Angle of plane and moulding irons, 25° for soft wood: 35° for hard wood.		
Breaking strain of band saws = 176 lbs. for each $\frac{1}{16}$ inch width of blade.		

Table 64.—Speed of Grindstones for Grinding Tools, &c.

Diameter of the grindstone, in inches	24	30	36	42	48	54	60	66	72	78	84	90	96
Number of revolutions of the stone per minute . . .	130	106	88	75	66	58	52	48	44	40	37	35	33

SPEED AND PROPORTIONS OF FANS.

Speed of fan for smithy fires 185, and for a cupola 270 feet per second of circumference.

Fan blades = $\frac{1}{4}$ diameter of fan each way.

Inlet = $\frac{1}{2}$ diameter of fan.

Outlet = area of blades.

Length of neck of spindle = $4\frac{1}{2}$ times the diameter of the spindle.

To find the horse-power required for a fan.—*Rule:* Divide the square of the velocity of the tips of fan in feet per second by 1000, and multiply the result by the density of the blast in ounces per inch, which product multiply by the area of discharge at the tuyeres in square inches, and divide the result by 963.

To find the density of fan blast in ounces per inch.—*Rule:* Divide the velocity in feet per second of the circumference by 4, square the result, and next divide by the product of the diameter of fan in feet by 120.

WHEEL CUTTING.

The Dividing Wheel on the mandrel of a wheel-cutting machine, is a worm-wheel, having usually 180 teeth; the change-wheel on the end of the worm-shaft is called the tangent-wheel, which is geared with an intermediate wheel or wheels, to the wheel on the end of the division-plate shaft. When convenient, the tangent-wheel should have the same number of teeth as that of the wheel to be cut, and the wheel on the division-plate shaft should have half the number of that of the dividing wheel, then two turns of the handle if the worm has a single thread, and one turn if it has a double thread, will give the required number of teeth to be cut. When this arrangement is not convenient, the change wheels may be found thus. Find the ratio between the number of teeth in the wheel to be cut, and that of the dividing wheel, which may be divided by any suitable number, when the numerator will represent the driver or division-plate wheel, and the denominator the driven or tangent-wheel. Thus, to cut a wheel with 90 teeth $\frac{180 \text{ dividing wheel } \div 2}{90 \text{ wheel to be cut } \div 2} = \frac{90}{45}$ the wheels required, with one turn of the handle if a single-thread worm, or with half a turn if the worm has a double-thread.

Table 65.—TABLE OF CHANGE WHEELS FOR A WHEEL-CUTTING MACHINE HAVING A DIVIDING WHEEL WITH 180 TEETH.

Number of Teeth to be Cut.	Number of Turns of the Handle.	Wheel on Division Plate Shaft.	Tangent Wheel on Worm Shaft.	Number of Teeth to be Cut.	Number of Turns of the Handle.	Wheel on Division Plate Shaft.	Tangent Wheel on Worm Shaft.	Number of Teeth to be Cut.	Number of Turns of the Handle.	Wheel on Division Plate Shaft.	Tangent Wheel on Worm Shaft.
10	4	90	20	53	2	90	53	96	1	90	48
11	4	90	22	54	2	90	54	97	2	90	97
12	4	75	20	55	2	90	55	98	1	90	49
13	4	90	26	56	2	90	56	99	2	90	99
14	4	90	28	57	2	90	57	100	1	90	50
15	4	60	20	58	2	90	58	101	2	90	101
16	4	90	32	59	2	90	59	102	1	60	34
17	4	90	34	60	2	90	60	103	2	90	103
18	4	50	20	61	2	90	61	104	1	45	46
19	4	90	38	62	2	90	62	105	1	60	35
20	4	45	20	63	2	90	63	106	1	90	53
21	4	90	42	64	2	90	64	107	2	90	107
22	4	90	44	65	2	90	65	108	1	60	36
23	4	90	46	66	2	90	66	109	2	90	109
24	4	30	16	67	2	90	67	110	1	90	55
25	4	45	25	68	2	90	68	111	1	60	37
26	4	90	52	69	2	90	69	112	1	90	56
27	4	40	24	70	2	90	70	113	2	90	113
28	4	45	28	71	2	90	71	114	1	90	57
29	4	90	58	72	2	90	72	115	2	90	115
30	4	60	40	73	2	90	73	116	1	90	58
31	4	90	62	74	2	90	74	117	1	60	39
32	4	90	64	75	2	90	75	118	1	90	59
33	2	90	33	76	2	90	76	119	2	90	119
34	2	90	34	77	2	90	77	120	1	90	60
35	2	90	35	78	2	90	78	121	2	90	121
36	2	90	36	79	2	90	79	122	1	90	61
37	2	90	37	80	2	90	80	123	1	120	82
38	2	90	38	81	2	90	81	124	1	45	31
39	2	90	39	82	2	90	82	125	1	72	50
40	2	90	40	83	2	90	83	126	1	60	42
41	2	90	41	84	2	90	84	127	2	90	127
42	2	90	42	85	2	90	85	128	1	45	32
43	2	90	43	86	2	90	86	129	1	60	43
44	2	90	44	87	2	90	87	130	1	90	65
45	2	90	45	88	2	90	88	131	2	90	131
46	2	90	46	89	2	90	89	132	1	45	33
47	2	90	47	90	1	90	45	133	2	90	133
48	2	90	48	91	2	90	91	134	1	90	67
49	2	90	49	92	2	90	92	135	1	60	45
50	2	90	50	93	2	90	93	136	1	45	34
51	2	90	51	94	1	90	47	137	2	90	137
52	2	90	52	95	1	72	38	138	1	60	46

Table 65 *continued.*—Table of Change Wheels.

Number of Teeth to be Cut.	Number of Turns of the Handle.	Wheel on Division Plate Shaft.	Tangent Wheel on Worm Shaft.	Number of Teeth to be Cut.	Number of Turns of the Handle.	Wheel on Division Plate Shaft.	Tangent Wheel on Worm Shaft.	Number of Teeth to be Cut	Number of Turns of the Handle	Wheel on Division Plate Shaft.	Tangent Wheel on Worm Shaft.
139	2	90	139	164	1	45	41	189	1	60	63
140	1	45	35	165	1	60	55	190	1	90	95
141	2	90	141	166	1	90	83	191	2	90	191
142	1	90	71	167	2	90	167	192	1	30	32
143	2	90	143	168	1	45	42	193	2	90	193
144	1	45	36	169	2	90	169	194	1	90	97
145	1	72	58	170	1	90	85	195	1	60	65
146	1	90	73	171	1	60	57	196	1	90	98
147	1	60	49	172	1	45	43	197	2	90	197
148	1	45	37	173	2	90	173	198	1	90	99
149	2	90	149	174	1	60	58	199	2	90	199
150	1	60	50	175	1	36	35	200	1	45	50
151	2	90	151	176	1	90	88	201	1	60	67
152	1	45	38	177	1	60	59	202	1	90	101
153	1	60	51	178	1	90	89	204	1	60	68
154	1	90	77	179	2	90	179	205	1	36	41
155	1	36	31	180	1	90	90	206	1	90	103
156	1	45	39	181	2	90	181	207	1	60	69
157	2	90	157	182	1	90	91	210	1	60	70
158	1	90	79	183	1	60	61	212	1	45	53
159	1	60	53	184	1	45	46	213	1	60	71
160	1	90	80	185	1	36	37	214	1	90	107
161	2	90	161	186	1	90	93	215	1	36	43
162	1	90	81	187	2	90	187	218	1	90	109
163	2	90	163	188	1	45	47	220	1	36	44

Rule to prove the correctness of change wheels for the above wheel-cutting machine:—

Divide the number of teeth in the wheel on the division-plate shaft, by the number of teeth in the wheel on the worm-shaft; multiply the quotient by the number of turns of the handle, and the product will be equal to the quotient of the number of teeth in the dividing wheel divided by the number of teeth in the wheel to be cut.

SCREW-CUTTING.

A Single Train of change wheels for screw-cutting consists of 3 wheels:—viz., 1 wheel on the lathe-spindle, called the driver; 1 wheel on the lathe's leading screw called the driven wheel, and one intermediate wheel to connect these two wheels, called the stud-wheel. In a double train, 4 wheels are used: a stud-pinion gearing into the leading screw-wheel, being keyed on the same socket as the stud-wheel. The wheel on the lathe-spindle is the first driver, the stud-pinion is the second driver, the stud-wheel is the first driven wheel, and the leading screw-wheel is the second driven wheel.

The Number of Teeth in the change-wheels must have the same proportion as the number of threads per inch of the leading screw has to the number of threads per inch of the screw to be cut. Thus, to cut a screw of 8 threads per inch with a leading screw of 2 threads, wheels are required in the ratio of 4 to 1; say a wheel with 20 teeth on the lathe spindle, and a wheel with 80 teeth on the leading screw, connected with an intermediate wheel. When the number of threads to be cut does not exceed 12 per inch, a single train of wheels can be used. To cut a screw of a finer pitch than the leading screw, the following rules will give the required wheels:—

Rule 1. Place the number of threads per inch of the leading screw for a numerator, and the number of threads per inch of the screw to be cut for a denominator, then add a cipher to each, which will give the required change wheels. Thus, to cut a screw of 8 threads per inch, with a leading screw of 2 threads per inch:—$\frac{2 \text{ threads in leading screw}}{8 \text{ threads in screw to be cut}}$; adding a cipher = $\frac{20 \text{ driver}}{80 \text{ driven}}$.

The wheel representing the numerator is placed on the lathe-spindle, and the wheel representing the denominator on the leading screw.

Rule 2. When the number of threads to be cut is uneven: say $2\frac{3}{4}$ threads per inch, multiply the whole number by the denominator of the fraction; and multiply also the number of threads per inch of the leading screw by the same multiplier: $\frac{2 \text{ threads per inch in leading screw} \times 4}{2\frac{3}{4} \text{ threads per inch in screw to be cut} \times 4}$ $= \frac{8}{11}$. Add a cipher $= \frac{80 \text{ driver}}{110 \text{ driven}}$.

When the numbers of teeth of wheels as found by this rule are too large, they may be reduced by dividing them by any suitable common divisor; and, if too small, they may be increased by multiplying them by any suitable common multiplier.

When a double train, or 4 change-wheels, are used, fix upon any 3 wheels for the lathe-spindle and stud-wheels, and the fourth or leading screw wheel may be found by the following rule.

Rule 3. Multiply the number of teeth in the wheel on the lathe-spindle by the ratio of the screw to be cut and the leading screw; and by the number of teeth in the second driver or stud-pinion; and divide the product by the number of teeth in the first driven wheel. Thus, to cut a screw of 16 threads per inch with a leading screw of 2 per inch, the ratio is 8 to 1. Lathe-spindle wheel 20 teeth, stud-pinion or second driver 50 teeth, stud-wheel or first driven wheel 80 teeth; required the number of teeth in the leading-screw wheel. $\frac{20 \times 8 \times 50}{80} = 100$ teeth. The above arrangement will cut a right-hand thread.

To cut a left-hand thread, place another wheel between a driver and a driven wheel to reverse the motion of the saddle.

Rule 4. The wheels may also be found by assuming a pair of wheels in conjunction with Rule 1, say $\frac{100}{100}$, and by dividing one of the drivers and one of the driven wheels by any suitable number. Thus, to take the screws in the last example $\frac{2}{16}$, add a cypher, $\frac{20 \text{ driver}}{160 \text{ driven}}$. Assume a pair of wheels, $\frac{100 \text{ driver}}{100 \text{ driven}}$, then by dividing the first driven wheel and the second driver by two, the required wheels are: $\frac{20}{80}\ \frac{50 \text{ driver}}{100 \text{ driven}}$

Rule 5. To prove the correctness of the change-wheels when the screw to be cut is of finer pitch than the leading screw, multiply the driving wheels together, and multiply the driven wheels together; and divide the greater product by the less. The quotient multiplied by the number of threads per inch of the leading screw, will give the number of threads per inch of the screw to be cut. To prove the wheels in the last example, $\frac{80 \times 100}{20 \times 50} = 8 \times 2 = 16$ threads per inch in the screw to be cut.

To Cut Coarse-Pitch Screws.—To find the change-wheels to cut a screw of coarser pitch than the leading screw, it is necessary to assume as many pairs of wheels as will sufficiently reduce the size of the first driver, the ratio of the wheels being the numerator (instead of the denominator as used for pitches finer than the leading screw in the above rules) in coarse pitches. *Rule*, multiply the pitch in inches of the screw to be cut, by the number of threads per inch of the leading screw, which will give the number of threads of the leading screw, in a length equal to the pitch to be cut. and therefore the ratio of the wheels required to cut the pitch. Thus, to cut a screw of 20-inch pitch with a leading screw of 2 threads per inch, $20 \times 2 = \frac{40}{1}$ the ratio required, the denominator must be increased by multiplying it by some suitable number to obtain a wheel of proper size, and the numerator must be increased in the same proportion, say 20, then, $\frac{40 \times 20}{1 \times 20} = \frac{800 \text{ first driver}}{20 \text{ first driven}}$. If two pairs of wheels are assumed, it will stand thus: $\frac{800 \text{ first driver,}}{20 \text{ first driven,}}\ \frac{100 \text{ second driver,}}{100 \text{ second driven,}}\ \frac{100 \text{ third driver}}{100 \text{ third driven}}$; to reduce the size of the first driver, divide the first driver and second driven by four, which will give wheels $\frac{200}{20}, \frac{100}{25}, \frac{100}{100}$; and to still further reduce the size of the first driver, divide the first driver and last driven by four, which will give $\frac{50}{20}, \frac{100}{25}, \frac{100 \text{ drivers}}{25 \text{ driven}}$, the wheels required.

Rule, to prove the correctness of the change-wheels for coarse-pitch screws, the screw to be cut being coarser in pitch than the leading screw. Multiply the driving wheels together, then multiply the driven wheels together, and multiply the product of the driven wheels by the number of threads per inch of the screw, with which product divide the product of the driving wheels. Thus, to prove the wheels in the last example :—

$\frac{50 \times 100 = 100}{20 \times 25 \times 25 \times 2} = \frac{500000}{25000} = 20$ inches pitch.

To Cut French Millimetre Pitches of Screws.—One millimetre pitch is the $\frac{1}{1000}$ part of a metre. One metre is approximately $39\frac{3}{8}$ inches, and a leading screw of $\frac{1}{2}$-inch pitch, or two threads per inch, has $39\frac{3}{8} \times 2 = 78{\cdot}75$ threads in one metre of its length; hence the proportion is $\frac{78{\cdot}75}{1000}$, which, if reduced by, say, multiplying by ·8, gives $\frac{78{\cdot}75 \times {\cdot}8}{1000 \times {\cdot}8} = \frac{63}{800}$, and the numerator 63 is a constant number, by which the number of millimetres, in the pitch of the screw to be cut, is to be multiplied.

Example :—To find the change wheels to cut a pitch of 8 millimetres, with the above leading screw: $8 \times 63 = 504$, then $\frac{504}{800}$ resolved into fractions becomes $\frac{63 \times 8}{80 \times 10}$ and by adding a cypher to the number 8 and another to the number 10, the required wheels to cut 8 millimetres pitch, are $\frac{63 \times 80 \text{ drivers}}{100 \times 80 \text{ driven}}$.

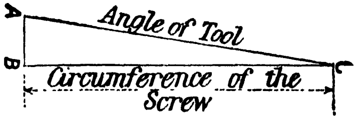


Fig. 146.- Angle of screw cutting Tool.

To find the angle to be given to a tool in order to cut a square-thread screw without injury to the sides of the threads. In Fig. 146, draw the line AB, equal to the pitch of the screw; draw the horizontal line BC, equal to the circumference of the screw, then draw the line AC, which gives the angle of the screw-cutting tool.

Price of Machined-Work, &c.—The following figures will give some idea of the price charged per hour for the use of machine-tools—workmen's wages and trade expenses being an additional charge.

Grindstones, 1*s.* 3*d.* per hour.—Emery Wheels, 1*s.* 6*d.*—Glaziers, 2*s.* 0*d.*—Lathes, 6 to 8 inch Centre, 1*s.* 6*d.*: 9 to 12 inch, 2*s.* 0*d.*: 13 to 16 inch, 2*s.* 6*d.*: 17 to 22 inch, 3*s.*: 24 to 30 inch, 4*s.*—Surfacing Lathe, medium sized, 4*s.*: large, 5*s.*—Planing Machines, $1\frac{1}{2}$ to $2\frac{1}{2}$ feet wide, 2*s.*: 3 to 4 feet wide, 3*s.*: $4\frac{1}{2}$ to $5\frac{1}{2}$ feet wide, 4*s.*: 6 to 8 feet wide, 5*s.*—Shaping and Slotting Machines, 4 to 6 inch Stroke, 1*s.* 6*d.*: 8 to 12 inch Stroke, 2*s.*: 13 to 15 inch Stroke, 2*s.* 6*d.*: 16 to 18 inch Stroke, 3*s.*: 20 to 24 inch Stroke, 4*s.*—Vertical Drilling Machine, small, 1*s.* 6*d.*: medium sized, 2*s.*: large, 3*s.* 6*d.*- Radial Drilling Machine, small, 2*s.*: large, 3*s.* 6*d.* - Cylinder Boring Machine, small, 2*s.* 6*d.*: medium size, 4*s.*—Slot Drilling Machines, 2*s.*—Screwing Machine, up to $1\frac{1}{2}$ inches, 2*s.*: up to 2 inches, 2*s.* 6*d.*—Milling Machine, 2*s.* 6*d.*—Wheel-Cutting Machine, 3*s.*—The price of Fitters' Best Work per day is equal to double the wages for ordinary work; $2\frac{1}{2}$ times for special or intricate work; and 3 times the wages for very exact work. Planing work per square foot, for large flat work, 4*s.*: for small ditto, 6*s.*: 5*s.* for angles; and 6*s.* for undercut work. Turning work per square foot for large plain turning and surfacing work = the same prices as for planing.

Table 66.—Change Wheels for Screw-cutting. Leading Screw, 2 Threads per Inch.

Number of Threads in One Inch to be cut.	Drivers.		Driven.		Number of Threads in One Inch to be cut.	Drivers.		Driven.	
1	40	...	20	...	4¾	40	...	95	...
	80	...	40	...		20	100	50	95
	50	90	30	75		30	100	75	95
1¼	40	...	25	...	5	20	...	50	...
	80	...	50	...		30	...	75	...
	40	80	20	100		50	60	75	100
1½	60	...	45	...	5¼	40	...	105	...
	80	...	60	...		20	80	60	70
	40	60	20	90		40	60	70	90
1¾	40	...	35	...	5½	20	...	55	...
	80	...	70	...		40	...	110	...
	60	40	30	70		20	60	30	110
2	20	...	20	...	5¾	40	...	115	...
	90	...	90	...		20	40	20	115
	30	80	40	60		20	60	30	115
2¼	40	...	45	...	6	20	...	60	...
	80	...	90	...		30	...	90	...
	40	100	50	90		30	50	60	75
2½	40	...	50	...	6¼	40	...	125	...
	60	...	75	...		20	60	50	75
	30	80	50	60		40	60	75	100
2¾	40	...	55	...	6½	20	...	65	...
	80	...	110	...		40	...	130	...
	40	100	50	110		40	60	65	120
3	30	...	45	...	6¾	40	...	135	...
	40	...	60	...		20	40	30	90
	30	80	40	90		40	80	90	120
3¼	40	...	65	.	7	20	...	70	...
	80	...	130	...		30	40	60	70
	60	80	65	120		40	45	70	90
3½	40	...	70	..	7¼	40	...	145	...
	60	...	105	...		20	80	40	145
	50	60	70	75		30	60	45	145
3¾	40	. .	75	.	7½	20	...	75	..
	60	80	90	100		30	60	75	90
	40	60	45	100		30	80	90	100
4	20	...	40	...	7¾	40	...	155	...
	40	...	80	..		50	60	75	155
	30	80	40	120		30	60	45	155
4¼	40	...	85	.	8	20	...	80	...
	20	80	40	85		25	...	100	...
	30	80	60	85		20	60	40	120
4½	20	...	45	...	8¼	20	80	60	110
	40	...	90	...		20	40	30	110
	30	60	45	90		20	60	55	90

TABLE 66 *continued.*—CHANGE WHEELS FOR SCREW-CUTTING. LEADING SCREW, 2 THREADS PER INCH.

Number of Threads in One Inch to be cut.	Drivers.		Driven.		Number of Threads in One Inch to be cut.	Drivers.		Driven.	
8½	20	...	85	...	17	20	25	50	85
	30	50	75	85		20	50	85	100
	40	50	85	100		20	45	85	90
9	20	...	90	...	18	20	30	60	90
	20	80	60	120		25	30	75	90
	30	80	90	120		30	40	90	120
9½	20	...	95	...	19	20	30	60	95
	30	40	60	95		25	30	75	95
	40	45	90	95		30	40	95	120
10	20	...	100	...	20	20	25	50	100
	25	...	125	...		20	30	60	100
	30	40	75	80		20	60	100	120
10½	20	...	105	...	21	20	30	70	90
	20	40	60	70		20	40	70	120
	30	40	70	90		20	25	70	75
11	20	...	110	...	22	20	30	60	110
	20	30	55	60		25	30	75	110
	20	45	55	90		30	40	110	120
11½	20	...	115	...	23	20	25	50	115
	40	50	100	115		25	30	75	115
	25	40	50	115		20	30	60	115
12	20	...	120	...	24	20	25	75	80
	30	40	80	90		20	30	80	90
	30	50	90	100		20	40	80	120
12½	20	...	125	...	25	20	25	50	125
	20	60	75	100		20	30	75	100
	20	40	50	100		25	40	100	125
13	20	30	60	65	26	20	45	90	130
	20	45	65	90		20	30	60	130
	25	40	65	100		20	40	80	130
13½	20	40	60	90	27	20	40	90	120
	20	40	45	120		20	25	75	90
	20	80	90	120		25	30	75	135
14	20	25	50	70	28	20	30	70	120
	20	45	70	90		20	25	70	100
	20	40	70	80		25	30	100	105
14½	20	...	145	...	29	20	20	40	145
	20	30	30	145		20	40	80	145
	30	40	60	145		20	45	90	145
15	20	...	150	...	30	20	40	100	120
	20	40	50	120		20	20	75	80
	30	40	75	120		20	25	75	100
16	25	30	75	80	32	20	25	80	100
	20	50	80	100		20	30	80	120
	20	75	120	100		25	30	100	120

Table 67.—CHANGE WHEELS FOR SCREW-CUTTING. LEADING SCREW, 3 THREADS TO THE INCH.

Number of Threads per Inch to be Cut.	Wheel on Mandrel.	Wheel on Leading Screw.	Number of Threads per Inch to be Cut.	Wheel on Mandrel.	Stud Wheel.	Pinion.	Wheel on Leading Screw.
1	60	20	10½	20	...	...	70
1¼	60	25	11	30	...	...	110
1½	60	30	11½	30	...	...	115
1¾	60	35	12	20	...	...	80
2	60	40	12½	30	...	...	125
2¼	60	45	13	30	...	...	130
2½	60	50	13½	30	...	...	135
2¾	60	55	14	30	50	70	100
3	60	60	15	20	...	...	100
3¼	60	65	16	20	40	30	80
3½	60	70	17	20	40	30	85
3¾	60	75	18	20	40	20	60
4	30	40	19	20	40	30	95
4¼	60	85	20	20	50	30	80
4½	30	45	21	20	60	30	70
4¾	60	95	22	20	40	30	110
5	30	50	23	30	40	20	115
5¼	60	105	24	20	40	30	120
5½	30	55	25	20	50	30	100
5¾	60	115	26	20	65	30	80
6	30	60	27	20	60	30	90
6¼	60	125	28	20	70	30	80
6½	30	65	29	20	40	30	145
7	30	70	30	20	60	30	100
7½	30	75	32	25	80	30	100
8	30	80	34	30	60	15	85
8½	30	85	36	30	60	15	90
9	30	90	38	30	60	15	95
9½	30	95	40	30	60	15	100
10	30	100	48	20	80	25	100

Whitworth's Standard Screw-Threads for Engineers' Taps.—The change wheels for cutting these threads are given in Table 83, page 271 ; and the proportions of screws and bolts in Table 89.

Whitworth's Standard Gas Screw-Threads, for gas piping.—The change wheels for cutting these threads are given in Table 86.

Whitworth's Standard Screw-Threads for Hydraulic Pipes, and gas and water pipes—and the correct thickness of metal for these pipes—are given in Table 88.

Whitworth's Standard Screw-Threads for Watch and Instrument Makers are given in Table 90.

Whitworth's Standard Sizes for Nuts and Bolt Heads are given in Table 108.

Table 68.—CHANGE WHEELS FOR SCREW-CUTTING. LEADING SCREW, 4 THREADS TO THE INCH.

Threads per Inch.	Wheel on Mandrel.	Wheel on Leading Screw.	Threads per Inch.	Wheel on Mandrel.	Wheel on Stud.	Pinion.	Leading Screw.	Threads per Inch.	Wheel on Mandrel.	Wheel on Stud.	Pinion.	Leading Screw.
1	80	20	9	80	30	15	90	34	30	45	15	85
1¼	80	25	10	60	25	15	90	36	40	60	15	90
1½	80	30	11	80	30	15	110	38	30	45	15	95
1¾	80	35	12	100	60	15	75	40	30	50	15	90
2	90	45	13	80	60	15	65	44	30	55	15	90
2¼	80	45	14	60	35	15	90	48	20	40	15	90
2½	80	50	15	80	45	15	100	50	20	50	15	75
2¾	80	55	16	60	45	15	80	54	20	45	15	90
3	100	75	17	60	45	15	85	57	20	45	15	95
3¼	80	65	18	80	60	15	90	60	20	50	15	90
3½	80	70	19	80	60	15	95	66	20	55	15	90
3¾	80	75	20	60	45	15	100	70	20	70	15	75
4	90	90	21	40	45	15	70	76	30	90	15	95
4¼	80	85	22	60	45	15	110	80	30	90	15	100
4½	80	90	24	40	45	15	75	96	20	80	15	90
5	80	100	26	60	65	15	90	100	20	75	15	100
5½	80	110	28	60	70	15	90	110	20	75	15	110
6	60	90	30	60	75	15	90	114	20	90	15	95
7	40	70	32	30	40	15	90	120	20	90	15	100
8	40	80	33	40	55	15	90	132	20	90	15	110

The above table will suit a lathe with a leading screw of ½ inch pitch by dividing the mandrel wheel by 2.

Cutting Right-hand and Left-hand Screws.—In cutting a right-hand thread, the tool in a lathe travels from right-hand to left-hand, and in cutting a left-hand thread, the tool travels from left-hand to right-hand.

Double and Treble Threads.—The distance between the centres of the threads of a screw is only one-half the actual pitch in a double-thread screw, and one-third the pitch in a treble-thread screw. To cut double or treble threads, find the wheels to cut a screw of the required pitch with a single thread, and multiply the number of teeth in the lathe spindle-wheel by the number of threads to be cut—that is, by 2 for a double-thread, or by 3 for a treble-thread—the product will be the number of teeth in the lathe spindle-wheel; the other wheels to complete the set will be the same as for a single thread. In cutting a double-thread screw, a single thread is first cut, a mark is then placed on a tooth of the lathe spindle-wheel and on the space it occupies in the first driven wheel, the change wheels are thrown out of gear and the lathe spindle is turned round, and the wheels are re-placed in gear at one-half the number of teeth of the wheel beyond the marked tooth; the lathe is then ready for cutting the second thread. The wheels for cutting three or more threads can be found in a similar way.

Table 69.—Change Wheels for Screw-cutting. Leading Screw, ⅜ Inch Pitch.

Number of Threads in One Inch.	Drivers.		Driven.		Number of Threads in One Inch.	Drivers.		Driven.	
1	80	...	30	...	12	30	40	60	90
1¼	80	100	50	75	12½	20	40	50	75
1½	80	100	50	90	13	20	40	60	65
1¾	40	80	30	70	13½	20	80	90	90
2	80	...	60	...	14	20	40	60	70
2¼	60	80	90	45	14½	20	40	75	58
2½	80	...	75	...	15	20	40	50	90
2¾	40	80	30	110	15½	20	40	62	75
3	80	...	90	...	16	20	40	60	80
3¼	50	80	65	75	16½	20	40	55	90
3½	30	80	45	70	17	20	40	60	85
3¾	40	80	60	95	18	20	40	60	90
4	40	...	60	...	19	20	40	60	95
4¼	40	80	60	85	20	20	30	50	90
4½	20	80	30	90	21	20	40	70	90
4¾	40	80	60	95	22	20	40	60	110
5	40	...	75	...	23	20	40	60	115
5¼	20	80	45	70	24	20	40	80	90
5½	30	80	45	110	25	20	40	75	100
5¾	40	80	60	115	26	20	40	65	120
6	30	80	60	90	27	20	40	90	90
6½	40	60	65	90	28	20	30	70	90
7	40	60	70	90	30	20	40	90	100
7½	30	80	75	90	32	20	25	75	80
8	30	...	90	...	34	20	20	60	85
8½	30	40	45	85	36	20	20	60	90
9	20	80	60	90	38	20	20	60	95
9½	20	40	30	95	40	20	20	75	80
10	20	80	60	100	42	20	30	70	90
10½	20	80	70	90	44	20	30	90	110
11	20	80	60	110	48	20	30	90	120
11½	20	40	30	115	50	20	30	75	150

The above Table will suit a lathe with a leading screw of ¾ inch pitch by dividing the first driving-wheel by 2.

Weight of Screws.—The weight of a screw with a single thread is approximately equal to that of a solid bar, whose diameter is equal to the diameter of the screw minus the depth of thread. Thus, the weight of a single-thread screw, of 3 inches diameter, with a thread ½ inch deep, would equal that of a solid bar—of the same material—of 2½ inches diameter.

The Strength of Screws and Bolts is given at pages 303 and 304. The proportion of V and square threads are given at page 276.

Table 70.—CHANGE WHEELS FOR CUTTING WHITWORTH'S SCREW THREADS FOR GAS, WATER, AND HYDRAULIC IRON PIPING. LEADING SCREW, 2 THREADS PER INCH.

Internal Diameter of Pipe.	Number of Threads per Inch.	Wheel on Lathe Spindle.	Wheel on Leading Screw.	Intermediate Wheel.	Stud Pinion.
Inch.					
⅛	28	20	120	70	30
¼	19	20	95	60	30
⅜	19	20	95	60	30
½	14	20	80	70	40
⅝	14	20	80	70	40
¾	14	20	80	70	40
⅞	14	20	80	70	40
1	11	20	110	...	...

NOTE.—All larger sizes of piping have 11 threads per inch.

Table 71.—CHANGE WHEELS FOR CUTTING SCREWS FROM ¼ INCH TO 4 INCH PITCH. LEADING SCREWS, ¼, ⅜, AND ½ INCH PITCH.

Pitch of Thread to be Cut.	LEADING SCREW ¼ IN. PITCH.				LEADING SCREW ⅜ IN. PITCH.				LEADING SCREW ½ IN. PITCH.			
	Drivers.		Driven.		Drivers.		Driven.		Drivers.		Driven.	
Inches.												
¼	50		50		50		75		50		100	
5/16	50		40		40		48		50		80	
⅜	60		40		50		50		45		60	
7/16	70		40		70		60		35		40	
½	50		25		40		30		50		50	
9/16	45		20		45		30		45		40	
⅝	50		20		50		30		50		40	
11/16	55		20		55		30		55		40	
¾	60		20		60		30		60		40	
13/16	65		20		65		30		65		40	
⅞	70		20		70		30		70		40	
15/16	75		20		75		30		75		40	
1	40	50	20	25	40	50	30	25	80	50	80	25
1⅛	90	60	60	20	90	60	60	30	90	60	60	40
1¼	50	80	40	20	50	80	40	30	50	80	40	40
1⅜	40	110	40	20	40	110	40	30	40	110	80	20
1½	50	60	25	20	40	60	30	20	50	60	40	25
1⅝	70	65	20	35	65	70	30	35	65	70	35	40
1¾	70	80	40	20	70	80	40	30	70	80	80	20
2	120	80	30	40	120	80	40	45	120	80	40	60
2¼	120	90	30	40	120	90	40	45	120	90	40	60
2½	120	100	30	40	120	100	40	45	120	100	40	60
2¾	120	110	30	40	120	110	40	45	120	110	40	60
3	120	100	20	50	120	90	30	45	120	90	30	60
4	120	100	25	30	120	80	20	45	120	80	20	60

Table 72.—CHANGE WHEELS FOR CUTTING PITCHES IN MILLIMETRES, FOR LATHES WITH LEADING SCREWS OF $\frac{1}{4}$, $\frac{3}{8}$ AND $\frac{1}{2}$ INCH PITCH.

Pitch of Screw to be Cut.	LEADING SCREW $\frac{1}{4}$ INCH PITCH.				LEADING SCREW $\frac{3}{8}$ INCH PITCH.				LEADING SCREW $\frac{1}{2}$ INCH PITCH.			
	Drivers.		Driven.		Drivers.		Driven.		Drivers.		Driven.	
Millimètres.												
1	36	35	80	100	36	35	100	120	36	35	160	80
2	35	45	50	100	35	45	75	100	63	20	100	80
3	63	30	50	80	63	30	75	80	63	30	100	80
4	63	40	50	80	63	40	75	80	63	40	100	80
5	63	50	50	80	63	50	75	80	63	50	100	80
6	63	60	50	80	63	60	75	80	63	60	100	80
7	63	70	50	80	63	70	75	80	63	70	100	80
8	63	80	50	80	63	80	75	80	63	80	100	80
9	63	90	50	80	63	90	75	80	63	90	100	80
10	63	100	50	80	63	100	75	80	63	100	100	80
11	63	110	50	80	63	110	75	80	63	110	100	80
12	63	60	50	40	63	60	50	60	63	60	100	40
13	63	65	50	40	63	65	75	40	63	65	80	50
14	63	70	40	50	63	70	75	40	63	70	80	50
15	63	75	40	50	63	75	75	40	63	75	80	50
16	63	80	40	50	63	80	60	50	70	45	50	50
17	63	85	40	50	63	85	75	40	63	85	80	50
18	63	90	40	50	63	90	60	50	63	90	80	50
19	63	95	40	50	63	95	60	50	63	95	80	50
20	63	100	40	50	63	100	60	50	63	100	80	50
21	63	105	40	50	63	105	60	50	63	105	80	50
22	63	110	40	50	63	110	60	50	63	110	80	50
24	63	60	20	50	63	60	30	50	63	60	50	40
25	70	90	40	40	70	90	40	60	70	90	80	40
26	63	65	25	40	63	65	25	60	63	65	50	40
28	63	70	20	50	63	70	30	50	63	70	50	40
30	63	90	40	30	63	90	40	45	63	90	80	30
32	63	60	30	25	63	60	45	25	63	60	50	30
34	63	85	40	25	63	85	60	25	63	85	80	25
35	63	70	40	20	63	70	60	20	63	70	80	20
36	63	90	50	30	63	90	50	30	63	90	50	40
38	63	95	40	25	63	95	60	25	63	95	50	40
40	63	80	40	20	63	80	40	30	63	80	40	40
42	63	105	40	25	63	105	60	25	63	105	40	50
44	63	110	40	25	63	110	60	25	63	110	40	50
45	63	90	40	20	63	90	60	20	63	90	80	20
46	63	115	40	25	63	115	60	25	63	115	80	25
48	63	90	30	25	63	90	45	25	63	60	40	25
50	63	75	30	20	63	75	45	20	63	75	40	60

Millimetre pitches are the best for small screws. Where very grea ccuracy is required, a wheel with 127 teeth should be substituted for th 3 wheel in the above table, and the remainder of the set of wheels altere ccordingly.

CAST-IRON AND IRON CASTINGS.

The Brands of Iron used in foundries for ordinary castings are Nos. 1, 2, 3, and 4, which are grey cast-irons. The quality of the iron can be judged by inspecting the fracture. When the colour of the fracture is a uniform dark grey with high metallic lustre, the iron is tough; but when the colour is dark grey, mottled, and without lustre, it is very weak. When the colour is lightish grey, with high metallic lustre, the iron is tough and hard; but when the colour is light grey, without metallic lustre, it is hard and brittle. When the colour is dull white, the iron is harder and more brittle than the last named one. When the colour is greyish white, with small radiating crystals, the iron is extremely hard and brittle. No. 1 has a dark grey fracture, with high metallic lustre; it is more fusible and more fluid than the others; but being deficient in hardness and strength, it is only suitable for very light castings. Nos. 2 and 3 are used for ordinary castings, the colour being a lighter grey, with a less degree of lustre than No. 1.

The Brands used for the manufacture of wrought-iron are Nos. 4, 5, 6—grey forge-iron; No. 7 is a mottled iron; and No. 8 is a white cast-iron.

Strength of Cast-iron.—The average strength of cast-iron to resist a crushing or breaking strain of compression is 42 tons per square inch of section, and its safe working strength in compression free from flexure is:—for cast-iron pillars, girders, and similar castings carrying dead weights, $\frac{1}{6}$th the breaking strain, or 7 tons: for pillars and machinery subject to vibration, $\frac{1}{8}$th, or $5\frac{1}{4}$ tons; and for cast-iron arches, $\frac{1}{14}$th of the breaking strain, or 3 tons per square inch of section. The average tensile strength of cast-iron, is 6 tons per square inch of section, and its safe working strength in tension, is $\frac{1}{4}$th the breaking strain, or $1\frac{1}{2}$ tons per square inch of section.

Testing Cast-iron.—A bar of good cast-iron, 1 inch square × 3 feet 6 inches long, placed upon supports 3 feet apart, should bear a gradually applied weight of 7 cwt. In contracts for castings, it is usual to specify the weight which a test-bar, cast from the same metal as the castings, shall carry, the usual stipulation being that a test-bar of cast-iron, 3 feet 6 inches long × 2 inches deep × 1 inch thick, placed upon supports 3 feet apart, shall bear in the middle a gradually applied weight of from 27 to 30 cwt., which will cause a deflection of about $\frac{3}{8}$ inch. The permanent set, caused by the deflection, is not taken notice of. These test-bars generally break, when a weight of from $31\frac{1}{2}$ to 32 cwt. is applied in the middle. The average breaking strain is usually taken of several test-bars, to guard against the effect of flaws in the castings. Cast-iron should be twice run, of fine grain, uniform, and of even grey colour, easily filed, and soft enough to be slightly indented when struck with a hammer.

Castings.—The mixtures of cast-iron, found in practice to be most suitable for different kinds of work, are given in the following table.

Table 73.—MIXTURES OF METAL FOR VARIOUS CAST-IRON CASTINGS.

Very tough and hard cast-iron, for anvils, for steam hammers, and similar work	Hematite, No. 3	1 part.	
	Pontypool, No. 4	1 „	
	Clyde, No. 4	1 „	
	Monkland, No. 8	1 „	
Chilled cast-iron rolls, a mixture which chills about ¾ inches deep	Hematite, No. 5	5 parts.	
	Lilleshall, C. B.	5 „	
	Cleator white	4 „	
Chilled cast-iron rolls, a mixture which chills about 1¼ inches deep	Hematite, No. 5	10 parts	
	Lilleshall, C. B.	8 „	
	Cleator white	4 „	
	Brymbo	2½ „	
	Pontypool white	4 „	
Chilled cast-iron rolls, a mixture which chills about 2¼ inches deep	Hematite, mottled	1 part.	
	Hematite, No. 5	1 „	
	Blaenavon or Pontypool, C. B.	1 „	
Chilled cast-iron rolls, a mixture which chills from 2½ to 3 inches deep	Cleator white	4 parts.	
	Brymbo	4 „	
	Lilleshall, C. B.	8 „	
	Hematite, No. 3	6 „	
	Pontypool, No. 3	2 „	
Tough and durable cast-iron, for wheel gearing	Barrow hematite, No. 2	8 cwt.	
	Glengarnock, No. 2	4 ..	
	Good clean scrap	8 „	
Tough and durable cast-iron, for cylinders up to 1 inch thick	Pontypool, C. B. No. 4	10 cwt.	Melted and cast into pigs in order to mix properly.
	Clyde, No. 4	10 „	
Tough and durable cast-iron, for cylinders above 1 inch thick	Pontypool, C. B. No. 4	7 cwt.	Melted and cast into pigs in order to mix properly.
	Clyde, No. 4	7 „	
	Gartsherrie, No. 3	6 „	
Good mixture of cast-iron, for ordinary castings	Scotch mixed brands	5 cwt.	
	Weardale	6 „	
	Good clean scrap	9 „	
Good mixture of cast-iron for light castings	Scotch mixed brands	5 cwt.	
	Glengarnock, No. 1	6 „	
	Good clean scrap	9 „	

The strength of cast-iron is increased by remelting, up to 10 meltings.

GUN-METAL AND BRASS CASTINGS.

Brass-Furnace.—A simple and effective brass furnace is shown in Fig. 147. It is 15 inches square × 28 inches deep inside. Hole for flue, 7 inches × 10 inches. Chimney, 10 inches square inside by not less than 15 feet high; the furnace to be built of brick, lined with firebrick; the front fire-bar bearer is moveable, and slides forward to let the fire-bars drop down, when required This furnace will melt about 80 lb. of metal quickly and easily. A. shows the tongs for pouring the metal, and B. the tongs for lifting the crucible off the fire.

Brass-Melting.—The process of melting may be briefly described thus. After the fire is lighted, the crucible is placed over it, upside down, until properly heated, when it is put in its place with its bottom resting on a firebrick, to keep it off the bars. Coke is then filled round to steady it. Copper cut into small pieces is then placed in the crucible and melted. Afterwards tin is added, melted and mixed. When the metal comes to a proper heat for casting, if a piece of zinc be dropped into the crucible, it will immediately flare up; if it does not flare up, the metal is not at its proper casting heat. When ready, the rubbish is skimmed off the top, and the metal is poured into the moulds. The

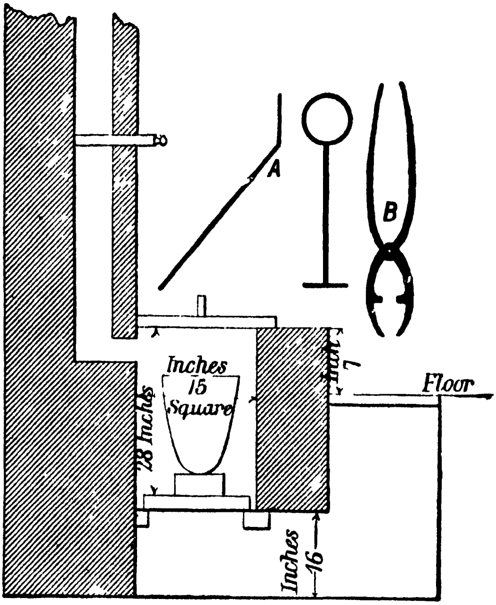


Fig. 147.—Furnace for Melting Brass.

moulding-boxes are opened as soon as the metal is poured, and the castings are sprinkled with water and cooled as quickly as possible, which makes the metal softer and more uniform than if left to cool slowly. The metals have also a tendency to separate, and the heaviest metal to sink to the bottom of the casting when the cooling takes place slowly. When old brass is melted down, no tin is necessary: but a small quantity of zinc is added. When a mixture of part old brass and part copper is melted, tin is added in proportion to the new copper, and zinc in proportion to the old brass. The tenacity of gun-metal varies considerably, because it depends greatly upon the manipulation of the metal both in the crucible and in the casting.

Copper loses its colour and softness when alloyed with other metals. Copper and tin mix well in all proportions. The addition of tin increases hardness, and, in order to be malleable, copper must be mixed with less than 10 per cent. of tin. A mixture containing one-third of tin is very brittle. Lead has the tendency to separate from copper, and cannot be used in larger proportions than ½ lb. to 1 lb. of copper. The tenacity of wrought-copper is 30,000 lbs. per square inch. In making castings of pure copper, to prevent blown castings, use a flux of ¾ lb. zinc for 50 lbs. copper.

Bronze or Gun-metal is the best alloy for bearings and general castings where toughness and durability are required. A good mixture is: copper, 9 parts; tin, 1 part. Its tenacity per square inch averages 28,000 lbs. The weight of one square foot 1 inch thick is 45 lbs., and of a piece 12 inches long × 1 inch square, is 3¾ lbs, approximately.

Good Brass, for light bearings and castings, consists of: copper, 7 parts; tin, 1 part; zinc, 1 part. Its tenacity per square inch averages 22,000 lbs. The weight of 1 square foot 1 inch thick is 44 lbs., and of a piece 12 inches long × 1 inch square 3·66 lbs. approximately.

Common Brass consists of: copper, 4 parts; tin, 1; and zinc, ½ part. Its tenacity per square inch averages 20,000 lbs. The weight of one square foot 1 inch thick is 43 lbs., and of a piece 12 inches long × 1 inch square, 3·55 lbs. approximately.

Yellow Brass, of best quality, consists of: copper, 2 parts; zinc, 1 part. Its tenacity per square inch averages 18,000 lbs. The weight of one square foot, 1 inch thick, is 42 lbs., and of a piece 12 inches long × 1 inch square, 3½ lbs. approximately.

Statuary-Bronze, or metal for statues, consists of: copper, 91·4 parts; tin, 1·7; zinc, 5·53; and lead, 1·37 parts. Another statuary bronze consists of: copper, 83 parts; tin, 4; zinc, 10; lead, 3 parts.

Aluminium-Bronze is a strong metal of variable composition, the strongest alloy being composed of copper, 90 parts; aluminium, 10 parts. Its tenacity per square inch is about 70,000 lbs., or more than double that of gun-metal. It is not liable to rust, and may be forged either hot or cold.

Sterro-Metal is a special metal for making heavy guns. Its tenacity per square inch is about 60,000 lbs., and consists of various proportions, one of which is: copper, 60 parts; zinc, 35 parts; tin, 2 parts; wrought-iron, 3 parts.

Muntz Metal consists of: copper, 3 parts: zinc, 2 parts. It is used for sheathing ships. Tenacity, 49,000 lbs. per square inch.

Malleable Brass can be forged either hot or cold. Consists of: copper, 56 parts; zinc, 42; wrought-iron, 2 parts.

Phosphor-Bronze is a superior metal for bearings, wheels, and other castings, where great strength, toughness, and durability are required. The tenacity per square inch of the toughest quality is about 56,000 lbs.: great care is required in the production of castings from this alloy. Unlike ordinary bronze, it can be remelted without injuring its quality.

A Non-corrosive Bronze is manufactured by the Phosphor Bronze Company, in sheets, rods, and tubes, and also in wire for overhead telegraph and telephone-wires and springs. Its tenacity when rolled and drawn into wire is from 100,000 to 150,000 lbs. per square inch.

Silicium-Bronze is a special alloy, manufactured by the Phosphor Bronze Company for electric conducting wire. It can be made to possess the strength of best iron wire with the conductivity of pure copper, or the strength of steel wire with twice its conductivity.

Compressed Bronze.—The compression of the metal while in a fluid state, by closing the blow-holes, caused by the formation of gas, increases its density and strength. Its tenacity is about 65,000 lbs. per square inch.

Ormolu is a metal used for ornaments of stoves and artistic metal work. It can be got up by finishing to a brilliant gold-like surface. It consists of from 2½ to 3 parts of copper, according to the depth of colour required, to 1 part of zinc. The castings after being polished are dipped in acid, and then brightened by means of a wire scratch-brush, and finally lacquered.

Rolled and Wire-Drawn Brass is stronger than cast brass. The metal during these processes becomes dense and hard, and requires to be frequently annealed by heating the metal and allowing it to cool slowly. The tenacity of the best quality of brass wire is 80,000 lbs. per square inch.

Bronze and Gun Metal for Bearings.—The greater the quantity of contained tin, the greater is the hardness of bronze and gun metal. The addition of a very little phosphorus increases the hardness and strength of the alloy. A small quantity of zinc is frequently added to make the metal run better, and to obtain good castings. Lead is sometimes added in small quantities to facilitate the turning of the metal, and in large quantities to reduce the cost of the alloy.

Lead is also frequently added for the purpose of reducing both the friction and wear of the alloy. In the results of the experiments given in the following table, the rate of the wear diminishes with the decrease of the tin, and also with the increase of the lead in the alloy. Hence, the rate of wear decreases with the diminishing compressive strength, or with the increased plasticity, of the alloy.

Table 73A.—RESULTS OF TESTS OF THE WEAR-RESISTING QUALITIES OF ALLOYS FOR BEARINGS.

Description of Alloy.	Copper.	Tin.	Lead.	Wear in grammes.	Relative Wear.	Wear per 1,000 kilometers in grammes.	Authority.
Gun metal	85·76	11·90	...	·2800	...	...	Mr. G. H. Clamer.
Gun metal	90·67	9·45	...	·1768	...	...	
Gun metal	95·01	4·95	...	·0776	...	...	
Gun metal	90·82	4·62	4·82	·0542	...	...	
Gun metal	85·12	4·64	10·64	·0380	...	...	
Gun metal	81·27	5·17	14·14	·0327	...	...	
Gun metal	75·00	5·00	20·00	·0277	...	...	
Gun metal	68·71	5·24	25·67	·0294	...	...	
Gun metal	64·34	4·70	31·22	·0130	...	...	
Phosphor bronze, ·8 phosphorus	79·70	10·00	9·60	...	1·00	...	Dr. Dudley.
Ordinary bronze	87·50	12·50	...	...	1·49	...	
Arsc. bronze, ·8 ars.	89·20	10·00	...	...	1·42	...	
Arsc. bronze, ·8 ars.	82·20	10·00	7·00	...	1·15	...	
Arsc. bronze, ·8 ars.	79·70	10·00	9·50	...	1·01	...	
Bronze	77·00	10·50	12·50	..	·92	...	
Bronze	77·00	8·00	15·00	...	·86	...	
Phosphor bronze with lead	...	...	...	...	...	$2\frac{53}{100}$	Kunzel.
Gun metal	82·00	18·00	...	...	...	$10\frac{1}{100}$	
White metal, 16 anti.	5·00	85·00	...	...	...	$11\frac{85}{100}$	
Gun metal	83·00	17·00	...	...	...	$11\frac{60}{100}$	
Lead composition, 16 anti.	...	...	84	...	...	$12\frac{30}{100}$	
White metal, 7 anti.	3·00	90·00	...	...	...	$14\frac{64}{100}$	

Hot Bearings.—The bearings of engines do not generally heat from pressure unless it exceeds that found by this rule. Maximum pressure in pounds per square inch of the horizontal sectional area of the journal = 400 ÷ $\sqrt[3]{}$ (velocity of rubbing surface in feet per second).

Table 73B.—COMPOSITION OF SOME LIGHT ALLOYS OF ALUMINIUM.

Description of Alloy.	Aluminium.	Zinc.	Copper.	Nickel.
Light alloy; rigid; like cast iron . Sp. G. 3·8	$66\frac{2}{3}$	$33\frac{1}{3}$	...	...
Light alloy; strong steel like castings Sp. G. 3·4	75	25	...	...
Light alloy for plates, 65 AL, 30 Z, 5 C, another is	80	15	5	...
Light alloy; soft and ductile	85	15	...	...
Light alloy; like brass . . 15 magnesium	85	...	...	...
Light alloy; malleable	94	...	4	2
Light alloy; easily worked	96	...	1	3
Light alloy; tough	98	...	1	1

Aluminium has little affinity for tin and lead. It should not therefore be an ingredient of alloys containing these metals.

Bronze, Gun Metal, Brass, and other Alloys.—The proportions of a variety of the alloys found in practice to be most suitable for different kinds of work are given in the following Table.

Table 74.—Mixtures of Metal for Bronze, Gun Metal, Brass, and Other Alloys.

Description of Work the Alloy is suitable for.	Number of Parts of			
	Copper.	Tin.	Zinc.	Lead.
Brass for watch-makers	1	...	2	...
Lap alloy	1	...	8	...
Yellow brass for various purposes	2	...	1	...
Locomotive brass tubes . . . 1 fine spelter	2	...	...	...
Button maker's brass . . . . . 8 brass	...	...	5	...
Bath metal . . . . 35 brass	...	...	9	...
Turner's brass . . . . . . 98 brass	...	...	...	2
Shot metal. . . . . 2 arsenic	...	...	...	98
Bullet metal . . . . 1 antimony	...	...	...	5
Sheet-brass, or Manheim gold metal	3	...	1	...
Electrical resistance alloy. . . . 2 nickel	4	...	1	...
Common brass for light castings	4	1	½	...
Brass for watch-makers; malleable.	4	...	1	...
Brass for cymbals and Chinese gongs	4	1	...	...
Pinchbeck	5	...	1	...
Dutch metal; worked into thin leaves for art work	5½	...	1	...
Gun metal for bearings and details of locomotives	5	. .	1	...
Ring gold . . . . . 5 gold; 3 silver	6	...	...	...
Metal for piston-rings . . . . 93 brass	7	...	...	...
Gun metal for bearings of engines	7	1	...	...
Gun metal for bearings of machinery	7	1	½	...
Gun metal for castings for machinery	7	1	1	...
Blanched copper . . . . ½ arsenic	8	...	...	...
Bronze for medals and art-castings . 3 nickel	8	...	3½	...
Pot metal for commonest water-taps	8	...	...	3
Gun metal for bearings of machinery and shafting	8	1	...	...
Gun metal for glands, spindles, and eccentric-straps	8	1	1	...
Gun metal for cocks, and valves for steam . .	9	1	...	...
Hardened copper ½ antimony; ⅛ silicon copper	10	...	...	...
Bronze for bearings of engines 1 phosphor tin	10	...	...	...
Bronze for bearings of engines ¼ phosphor copper	10	1	...	...
Hard b'ze for b'ings of engines ¼ phosphor copper	10	1½	...	...
Nickel bronze for castings . . . 17½ nickel	10	...	12½	...
White brass for various purposes	10	10	80	...
Brass for mathematical and other instruments. .	12	1	...	...
Hard gun metal for various purposes	12	1½	½	...

Table 74 *continued.*—MIXTURES OF METAL FOR BRONZE, GUN METAL, BRASS AND OTHER ALLOYS.

Description of Work the Alloy is suitable for.	Number of Parts of			
	Copper.	Tin.	Zinc.	Lead.
Gun metal for cocks, valves and taps for water	14	1	1	...
Metal for piston-rings; requires no lubrication	15	5	...	...
Imitation gold . . . . . . 7 platina	16	...	1	...
Bristol sheet brass; solders well	16	...	6	...
Gilding metl. hmrd. into thin shts., 80 C, 20 Z, or	16	...	1¼	...
Brass which solders well	16	1	...	½
Gun metal for general purposes	16	1	1	½
Metal for brass rivets	16	2	1¼	...
Gun metal for covering iron pump rods	16	2	1	1
Tough gun metal for bolts, nuts and wheels	16	1½	½	...
Hard gun metal	16	2½	...	...
Anti-rust metal (Baily's metal) for instruments	16	2½	1	...
Metal for bearings exposed to heat	18	1	1	...
Dipping brass, 16 C, 14 Z; another is 6 spelter	19	...	...	...
Red metal . . . . . . 2½ antimony	20	...	...	...
Gun metal for general bearings; 75 scrap gn. mtl.	20	2½	...	2½
Gun metal for footsteps of vertical shafts	20	5	...	...
Gun metal for slide valves	22	4	1	...
Hard brass castings	25	4½	2	...
Bell metal for musical bells	25	4½	...	...
Bell metal for small clock bells	25	5	...	...
Bell metal for gongs	25	5½	...	..
Bell metal for house bells	25	6	...	...
Bell metal for larger bells for factories, &c.	25	6½	...	...
Bell metal for small church bells	25	7	...	...
Bell metal for the largest church bells	25	7½	...	...
Jeweller's metal . . . . . . 10 brass	30	7	...	...
Gun metal for general castings	32	3	1	...
Malleable brass; it can be forged hot	33	...	25	...
Copper flanges for pipes	36	1	4	...
Gun metal for pumps and other hydraulic purposes	36	4	1	...
Brass for gas fittings and other purposes	40	...	20	1
Speculum metal	43	20	...	...
For the buckets, rams, and valves of pumps	44	3	3	...
Hard mtl. 44 C, 6 T; metal for brass pans, very hd.	48	11	...	...
Brass for cocks and taps for water; 45 ylw. brass	50	...	...	5
Mosaic gold, princes metal, art metal, or spelter	50	...	50	...
Violet coloured, art metal . . 50 antimony	50	...	...	...
Gun metal for general castings	50	2	5	5
Brass for ornamental work	52	...	47	1
Anti-acid metal; 3·75 manganese, 1·25 aluminium	53	...	42	...
Strong brass	55	...	45	...
Strong brass for plates . . . . . ½ iron	56	1	42½	...
Hard brass	56	28	16	...

Table 74 *continued.*—MIXTURES OF METAL FOR BRONZE, GUN METAL, BRASS, AND OTHER ALLOYS.

Description of Work the Alloy is suitable for.	Number of Parts of			
	Copper.	Tin.	Zinc.	Lead.
Brass for bars and shafts	57	15	28	...
Brass for bolts	58	...	41	1
Mang. bronze castings 1·25 ir., ·12 mang., ·50 al.	57·50	...	41·13	...
Mang. bronze for screw propellers 1 mang., 1 al.	59	...	39	...
Manganese bronze 1½ mang., 1½ iron, 1 al.	60	...	36	...
Manganese bronze 1 iron, 1 mang., 1 nickel	61	...	36	...
Manganese bronze 1 iron, 1 mang., 1 al.	61	...	36	...
Mang. bronze, rolled sheets 1·25 iron, ·10 mang.	61	·65	37	...
Brass for castings	60	...	36	4
Strong brass for submerged work 3 iron	60	...	37	...
Brass to resist sea-water	60	1	39	...
Copper rivets 60 C, 1 T, brass for castings	60	9	30	1
Hard brass-plate 1½ iron	60	...	38½	...
Yellow brass	60	...	40	...
Brass castings	62	½	36	1½
Naval brass; very tenacious, used by Adm. 37 spel.	62	1	...	...
Anti-corrosive metal, to stand acids 7 antimony	63	...	...	30
Aluminium-brass 3½ aluminium	63¼	...	33¼	...
Metal for pumps 80 C, 5 T, 7½ Z, 7½ L, or	64	2½	33	½
Clamer's plastic gun metal for bearings 1 nickel	64	5	...	30
Gun metal for bearings of locomotive engines	64	7	1	...
Brass for cocks, taps, and unions	67	½	32	½
Yellow brass for castings	67	1	32	...
Brass wire 67 copper, 33 zinc, mirror metal	68¼	31¾	...	...
Metal for barometer dials 30 arsenic	70	...	...	...
Brass tubes for condensers and heaters 30 spelter	70	...	...	...
Yellow brass, fine	70	...	30	...
Strong brass for general castings	70	1	29	...
Anti-acid metal 7 antimony	70	3	...	20
Gun metal for bearings of engines ½ iron	70	5	10	14½
Art gun metal for ornamental work	72	1	27	...
Gun metal for bearings of engines and shafting	72	5	9	14
Gun metal for bearings of locomotive engines	74	9½	9½	7
Anti-acid gun metal ·10 phosphorus	75	9·9	...	15
Florentine art bronze	75	...	25	...
Gun metal for bearings of engines and machinery	76	9½	...	14½
Metal for bearings of railway axles ¼ phosphorus	76¾	8	...	15
Florentine art bronze	77	...	23	...
Antique bell metal	77	23	...	...
Antique bell metal	83	11	6	...
Gun metal for bearings of machinery and shafting	77	10½	...	12½
Hard gun metal for general purposes	77½	15½	7	...
Gun metal for bearings of engines and shafting	78	9	...	13
Gun metal for bearings of railway carriages	78	9½	...	12½

Table 74 *continued.*—MIXTURES OF METALS FOR BRONZE, GUN METAL, BRASS, AND OTHER ALLOYS.

Description of Work the Alloy is suitable for.	NUMBER OF PARTS OF			
	Copper.	Tin.	Zinc.	Lead.
Gun metal for bearings of railway carriages . .	78	20	2	...
Gun metal for bearings of engines and machinery	79	6	15	...
Gun metal for bearings of engines and machinery	79	8	5	8
Gun metal for bearings of railway carriages . .	79	10	...	11
Gun metal for bearings of locomotives ½ phosph.	79½	10	...	9½
Gun metal for gen. purposes 80 C, 6 T, 8 Z, 6 L, or	80	8	...	12
Gun metal for bearings of engines . . ½ nickel	80	10	...	9½
Gun metal for bearings of railway axles 8 arsenic	80	10	...	10
Gun metal for bearings of engines and machinery	80	14	2	4
Gun metal for bearings of engines and machinery	80	16	2	2
Metal for cymbals; worked hot	80½	19½	...	...
Gun metal for bearings of machinery . . .	81	4	3	2
Gun metal for bearings of engines . ½ nickel	81	10	8½	...
Gun metal for bearings of shaft. and mach. ¼ phos.	81	9	4	5¾
Gun metal for bearings of engines and machinery	81	13	4	2
Gun metal for bearings of engines and machinery	82	9	5	4
Gun metal for bearings of engines and machinery	82	10	8	...
Gun metal for bearings of engines and machinery	82	12	4	2
Gun metal for bearings of engines 82 C, 13 T, 5 Z, or	82	14	...	4
Gun metal for bear. of engines 82 C, 14 T, 2 Z, 2 L, or	82	16	2	...
Gun metal for bearings of valve-spindles . .	82	15	3	...
Gun metal for bearings of railway axles . . .	82	18	...	...
Gun metal for bearings of machinery . . .	82¾	12¾	3½	1
Gun metal for general purposes	83	6	10	1
Gun metal for screw propellers	83	10	7	...
Gun metal for bearings of motor cars . . .	83	14½	2	½
Gun metal for bearings of railway axles . .	83	15	3	...
Bearings for rail. axles 83½ C, 16½ T, ½ lb. Z, ½ lb. L, or	83	17	...	...
Gun metal for bearings of engines and machinery	83½	9½	4	2
Electrical resistance alloy 4 nickel; 12 manganese	84	...	...	...
Gun metal for bearings of engines ¼ phosphorus	84	6	...	9¾
Gun metal for bearings of engines and machinery	84	7	...	9
Gun metal for general castings	84	10	4	2
Gun metal for engine work; either 84 C, 12 T, 4 Z, or	84	12	2	2
Gun metal for slide-valves and bearings . .	84	13	2	1
Gun metal for bearings of loco. 84 C, 14 T, 2 Z, or	84	16	...	...
Gun metal for bearings of rolls ¼ phosphorus	85	7	¾	7
Gun metal for rams of pumps, valves, and bearings	85	10	...	5
Gun metal for bearings of engines and machinery	85	14	...	1
For bearings . . 85¾ C, 14¼ T, ½ lb. Z, ½ lb. L, or	85	12	2	1
Gun metal for toothed wheels	85	13	1	1
Gun metal for railway carriage bearings . .	85	15	...	...
Gun metal for bearings of engines and millwork .	86	6	4	4
Gun metal for valves for high pressure water .	86	9	4	1

Table 74 *continued.*—MIXTURES OF METAL FOR BRONZE, GUN METAL, BRASS, AND OTHER ALLOYS.

Description of Work the Alloy is suitable for.	Number of Parts of			
	Copper.	Tin.	Zinc.	Lead.
Gun metal for valves & eng. work 86 C, 10 T, 4 Z, or	86	10	2	2
Gun metal for bearings and slide valves of engines	86	12	½	1½
Gun metal for hydraulic work, rolls and bearings	86	12	2	...
Gun metal for axle-boxes of carriages and carts	86	14	...	...
Gun metal for pumps	86½	10½	1½	1½
Gun metal for piston rings	86½	11½	1	1
Gun metal for bearings and other castings	86½	12	1½	...
Gun metal for hydraulic tubes . ½ phosphorus	86½	13	...	...
Gun metal for steam cocks and hot-water cocks	87	6	5	2
Gun mtl. for steam valves & cocks 87 C, 8 T, 5 Z, or	87	7	5	1
Gun metal for toothed wheels and other work	87	10	2	1
Gun metal for embossing press	87	11	2	...
Gun metal for straps and bolts	87½	6¼	6¼	...
Gun metal for motors and hydraulic work ¼ phos.	87½	12¼	...	...
Gun metal for art castings and machinery 1½ ant.	88	2¾	5½	2¼
Gun metal for statues and art castings	88	3	7	2
Gun metal for steam fittings and other castings	88	9	2	1
Gun metal for bearings and other castings	88	10	1	1
Admiralty gun metal; very tough	88	10	2	...
Gun metal for bearings on Indian railways	88	12	...	...
Gun metal for steam fittings	88½	9½	2	...
Bronze for bearings 89 C, 5 T, 5 Z, 1 mang., or	89	5	5	1
Bronze for bearings and other castings	89	8	2	1
Bearings for rlwy. axles Either 89 C, 8 T, 3 Z, or	89	9	2	...
Bronze for patterns	89¾	6¾	2¼	1¼
Bronze for general castings	90	5	5	...
Bronze for hydraulic castings . 4 phosphor tin	90	6	...	...
Bronze for patterns and other castings ½ nickel	90	6	2	1½
Bronze for rolling into plates	90	8	2	...
Bronze for motors and hydraulic work ¼ phosph.	90	9¾	...	...
Bronze for bearings and other parts of engines	90	10	...	...
Red brass, or tombac, for ornametal work	90	...	10	...
Bronze for general purposes	90½	6½	2	...
Bronze for bearings of locomotives ·10 manganese	90·5	9·4	...	...
Bronze for bearings of engines	91	6	1	2
Ordnance bronze	91⅔	8⅓	...	...
Bronze for piston rings	92	6	1	1
Bronze for stamping	92	7	1	...
Bronze for toothed wheels	92	8	...	...
Bronze for rolling into plates . . . ·10 iron	92·5	2·4	...	5
Imitation gold bronze 4·5 aluminium, ·5 silver	95	...	...	...
Bronze for medallions and art castings	96	4	...	...
Bronze for lining pumps for acid liquids	97	3	...	...
Metal for hammers and soldering bits ¼ phosph.	100	...	1½	...

Weight of Metal required for Castings of Alloys.—The weight of each of the different ingredients required for casting an alloy of given weight may be found as follows:—Suppose a casting weighing 50 lbs. is required, composed of 78 per cent. of copper, 9 per cent. of tin, 12 per cent. of lead, and 1 per cent of zinc.

Then the alloy consists of $78 + 9 + 12 + 1 = 100$ parts.

$$\text{The quantity of copper required is} = \frac{78 \times 50}{100} = 39{\cdot}0 \text{ lbs.}$$

$$\text{The quantity of tin required is} = \frac{9 \times 50}{100} = 4{\cdot}5 \text{ lbs.}$$

$$\text{The quantity of lead required is} = \frac{12 \times 50}{100} = 6{\cdot}0 \text{ lbs.}$$

$$\text{The quantity of zinc required is} = \frac{1 \times 50}{100} = {\cdot}5 \text{ lb.}$$

$$\overline{50{\cdot}0 \text{ lbs.}}$$

The Strength of Alloys of good quality is generally as follows:—

Table 74A.—TENSILE STRENGTH OF ALLOYS IN TONS PER SQUARE INCH.

Malleable bronze	48	Copper fire-box plate	15
Manganese bronze	40	Tough fine yellow brass	15
Ferro-bronze	36	Aluminium alloy, 2 AL., 1 Z.	15
Silicon-bronze	30	Aluminium alloy, 3 AL., 1 Z.	14
Nickel-bronze	26	Ordinary gun-metal	12
Brass, 60 C, 40 Z, annealed	22	Ordinary brass	7
Brass, 70 C, 30 Z, annealed	20	White bearing-metal	4
Tough fine bronze	18	Antimonial lead	3

Table 75.—WEIGHT OF BELLS.

Diameter of bell, in inches	6	7	8	10	12	14	16	20	25	30	35	40	45	50	60	70	80	91½
Weight, in lbs.	4½	6½	11	16	22	45	68	197	393	645	900	1345	1795	2580	2920	7952	11256	18228

Thickness of Bells.—To obtain variety of tone, the thickness of house bells should range from $\frac{1}{12}$th to $\frac{1}{24}$th of their diameter. Clock bells and dinner bells should be not less than $\frac{1}{14}$th of their diameter in thickness. Large church bells and peals of bells range from $\frac{1}{10}$th to $\frac{1}{14}$th the diameter in thickness at the sound bow. The clapper of small bells should be about $\frac{1}{30}$, and for large church bells from $\frac{1}{40}$ to $\frac{1}{60}$ the weight of bell.

The largest bells in England are:—Great Paul, of St. Paul's Cathedral, which is composed of 13 lbs. of copper to 4 lbs. of tin, and weighs 37,383 lbs.; Great bell of Westminster, weighs 30,352 lbs.; Manchester, 18,256 lbs.; Tom of Oxford, 17,360 lbs.; Tom of Exeter, 13,440 lbs.; Tom of Lincoln, 12,096 lbs.; and Tom of St. Paul's, weighs 11,474 lbs.

White Metal being one of the best alloys for reducing friction, is commonly called antifriction metal. It is cheaper than gun metal, but it is much softer and is liable to crush and spread out, unless cased in an iron box. Babbit's original receipt was: 4 lbs. copper; 8 lbs. antimony; 24 lbs. tin = 36 lbs. This was called hardening. For every lb. of the above he added 2 lbs. more tin, making altogether 108 lbs. There are many modifications of this alloy.

A great many antifriction alloys for bearings and for lining bearings have a base of lead, because it greatly reduces friction and the cost of production. Some of the numerous varieties of antifriction alloys in general use, and other alloys are given in the following table.

Table 76.—ANTIFRICTION WHITE METAL AND OTHER ALLOYS.

Description of Work the Alloy is suitable for.	Number of Parts of					
	Cop.	Zinc.	Nick.	Tin.	Antimony.	Lead.
Silver nkl. alloy of fine quality 2 slv.,	48	20	30	...	...	...
Silver-like metal for small castgs. 3 Al	57	20	20	...	...	
Silver-like metal for small cstgs. 3½ Al.	56½	20	20	...	...	...
White metal; resists sea-water 2 oz. Al.	50	35	15	...	...	...
Nickel alloy, or German silver ½ mang.	55½	30	12	...	...	2
Nickel alloy . . . . . ½ mang.	54½	20	15	...	...	10
Nickel alloy . . . . ½ mang.	49½	28	17	...	...	5
Nickel alloy of fine colour . ½ mang.	59½	20	20	...	...	...
Nickel alloy . . . . . 1 iron	53	20	25	...	...	1
White metal for ornamental castings .	55	45	...	...	...	...
White metal for ornamental castings .	56	20	...	...	24	...
White metal for patterns	...	50	...	50	...	...
White metal	...	50	...	25	...	25
White metal	1	52	...	46	1	...
White metal for bearings	2	54	...	44	...	...
Art metal for ornamental castings . .	43	57	...	...	...	...
White metal for bearings	4	60	...	20	3	13
White metal for bearings	5½	72	...	16	...	6½
White metal for bearings	6½	72	...	...	5½	16
White metal for bearings	6	75	...	18	...	1
White metal for general purposes . .	4	73	...	23	...	...
White brass for various purposes . .	5½	76	...	17½	...	1
White brass for various purposes . .	8	79	...	7	3	3
White metal for bearings of rly. wagns. .	6	80	...	14	...	...
White metal for bearings of engines . .	4	85	...	10	...	1
White metal for bearings	5	85	...	...	10	...
White metal for bearings	9	88	...	1	...	2
White metal for bearings	12	88	...	...	...	...
White metal for ornamental cstgs. 1 Al.	10	89	...	...	...	...
White metal for ornamental cstgs. 1¼ Al.	9½	89¼	...	...	...	...
Zinc bronze for ornamtl. cstgs. 1 iron	8	90	...	...	...	1
Zinc bronze for ornamental castings .	8	91	...	...	...	1
Zinc bronze for ornamental castings .	8½	91½	...	...	...	...

Table 76 *continued.*—ANTIFRICTION WHITE METAL AND OTHER ALLOYS.

Description of Work the Alloy is suitable for.	NUMBER OF PARTS OF			
	Tin.	Copper	Antimony.	Lead.
Nickel alloy for candlesticks . 1 zinc, 1 nickel	...	2	...	2½
Nickel alloy for spoons and forks 1 zinc, 1 nickel	...	2	...	...
Nickel alloy for knife handles 2 zinc, 2 nickel	...	4½	.	...
Nickel alloy for sheets . . 2 zinc, 2 nickel	.	5½	...	...
Nickel alloy for models . . 5 zinc, 3 nickel	1	10		5
White metal for pattern letters	2	...	..	1
White metal for pattern letters and metallic packing	3	...	...	2
Impression moulding alloy ; melts at 284° F. 5 bis.	3	...	...	2
White metal for small ornamental castings . .	3	...	¼	8
Metallic packing for rods 1 white bearing metal	.	...	...	9
White bell metal. . . . 1 antimony	7¼	..		...
White metal for bearings of railway axles . .	38	...	25	37
White metal for bearings	45	..	15	40
White metal for bearings of railway axles . .	42	.	16	42
White metal for bearings	45	.	13	42
White metal for bearings	28	.	28	44
White metal for bearings	34	6	16	44
White metal for bearings	35	4	17	44
White metal for bearings	40	5	10	45
White metal for bearings	38	2	10	50
White metal for bearings	20		20	60
White metal for bearings and metallic packing .	32	5	3	60
White metal for bearings	12	.	15	73
White metal for bearings	14	.	10	76
White metal for bearings . . ½ iron, ¼ zinc	1	..	20	78
White metal for bearings . . ¼ bismuth	4	2	16	77
White metal for bearings . . ¼ bismuth	6	...	15	78
White metal for bearings	6		15	79
White metal for bearings . . . 1 zinc		.	20	79
White metal for metallic packing and bearings .	12	.	8	80
Antimonial lead for bearings of railway wagons .	.	.	16	84
Antimonial lead for bearings of railway wagons .	...	.	13	87
White metal for lining bearings	1	..	5	94
White metal for lining bearings	1	...	4	95
White metal for lining bearings	1		3	96
White metal for buckles & buttons 16 brass, 2 zinc	1			
Electric amalgam . . . 4 mercury, 2 zinc	1		.	...
Electrum . . . . 7½ zinc, 8½ nickel		17	...	...
Imitation silver 3 oz. T, 1 lb. C, or 1 metall. arsenic	...	9	..	...
Imitation platinum . . 8 pale brass, 5 spelter				
Type metal, 2 A, 11 L ; stereotype metal 2 bismuth			4	18
Metal for vice-clams		...	1	10
Hard white metal . . . 20 brass, 3 spelter	1	...	...	...
Hard white metal . . . 16 brass, ½ zinc	1	...	...	1

Table 76 *continued.*—ANTIFRICTION WHITE METAL AND OTHER ALLOYS.

Description of Work the Alloy is suitable for.	Number of Parts of			
	Tin.	Copper.	Antimony.	Lead.
Metal for small bushes 1 scrap white b'ing metal	1	...	...	1
White metal for the bearings of light machinery .	1½	...	1	1½
Tutenag, 1 bis., 2 T; mtl. that ex'ds in c'ling, 1 bis.	...	...	2	9
Alloy for fusible plugs, sof'ns at 366°, mlts. at 372 F	2	...	...	2
Alloy for fusible plugs, sof'ns at 373°, mlts. at 383 F	2	...	...	6
Alloy for fusible plugs, sof'ns at 378°, mlts. at 388 F	2	...	...	7
Alloy for fusible plugs, sof'ns at 396°, mlts. at 408 F	2	...	...	8
White metal for bearings of machinery . .	2	...	2	24
White metal for models and instruments 1 brass	2	...	4	...
White mtl., 12 bis., 1 an., 20 L.; another is 13 zinc	2¼	35	...	...
Impression moulding alloy, melts at 212°F. 8 bis.	3	...	...	5
Metal for medals, 6 T, 1 an.; imitation silver, 1 zinc	5	4	...	1
White metal, 13 Z, 3 T, 1 C; another is 13 zinc	6	1	...	...
White metal for bearings of machinery . . .	6	1	2	...
White metal for bearings of machinery . .	8	1	2	9
White metal for bearings of machinery . . .	8	2	4	36
White metal for sockets . . . . 5 zinc.	8	5	...	8
Britannia metal, 10 T, 1 an.; Queen's metal, 1 bis.	9	...	1	1
White metal for bearings of engines and machinery	10	1	3	6
White metal for bearings of machinery . .	12	1	1	...
White metal for lining locomotive axle boxes . .	16	1½	2	...
White metal for bearings of engines and machinery	16	2	3	4
White metal for bearings of engines and machinery	22	1	2	...
White metal for general purposes . . .	24	4	8	...
White metal for bearings of machinery . . .	28	2	3	...
White metal for bearings of machinery . .	32	5	10	18
White metal for bearings of engines and machinery	36	1½	3	...
White metal for bearings of engines and machinery	40	5	10	...
White metal for bearings of machinery 1 bis.	42	2	5	...
White metal for bearings of motor cars . . .	48	4	1	...
Pewter, 79 T, 1 an, 20 L; or 100 T, 2 an; fine ptr, 1 bis	50	1	4	...
White metal for bearings of engines and machinery	50	1	5	...
White metal for bearings of engines and machinery	50	1½	5	...
White metal for bearings of engines and machinery	50	3	5	...
Metal for organ pipes	50	...	...	50
White metal for bearings of engines and machinery	56	3	4	...
White metal for bearings of engines and machinery	60	3	6	...
White metal for bearings of engines and machinery	60	7½	9	...
White metal for bearings of engines and machinery	62¾	3¾	8½	25
White mtl. for b'ing of engines and m'ch'ry 20 zinc	64	...	...	16
White mtl. for b'ing of engines and m'ch'ry 33 zinc	64	2	...	1
White metal for bearings of engine and machinery.	65	2½	2½	...
White metal for bearings of railway axles . .	67	22	11	...
White metal for bearings of machinery . .	68	9	8	15

Table 76 *continued.*—ANTIFRICTION WHITE METAL AND OTHER ALLOYS.

Description of Work the Alloy is suitable for.	NUMBER OF PARTS OF			
	Tin.	Copper.	Antimony.	Lead.
White metal for the bearings of engines . .	70¾	9¾	19½	...
White metal for metallic packing	71	5	24	...
White metal for bearings of engines and machinery	72	21	7	...
White metal for bearings of engines and machinery	72	5½	6½	16
White metal for bearings of engines and machinery	72	21	7	...
White metal for bearings of engines and machinery	73	2	25	...
White metal for metallic packing 4 phosphor C.	73	4	12	7
White metal for bearings of engines and machinery	73	9¼	17¾	...
White metal for bearings of railway axles . .	75	4	7	14
White metal for bearings of machinery . . .	76	1	4	...
White metal for bearings of machinery . .	76½	6½	17	...
White metal for bearings of shafting and engines	77	4	3	16
White metal for bearings of engines and machinery	77	8	15	...
White metal for bearings of railway axles . .	78	10	12	...
White metal for bearings of engines . . .	78½	3¾	11¾	6
White metal for bearings of engines . . .	79	2	19	...
White metal that resists some acids . . .	80	4	1	15
White metal for bearings of railway axles . .	80	5	15	...
White metal for bearings of engines and machinery	80	8	12	...
White metal for bearings of engines and machinery	80	10	10	...
White metal for bearings of engines and machinery	81	5¼	13¾	...
White metal for bearings of engines and machinery	81	6	13	...
White metal for filling perforations in slide-valves	82	6	12	...
White metal for bearings of engines and machinery	82	8	10	...
White metal for bearings of railway axles . .	83	6	11	...
White metal for bearings of engines and machinery	83	8¼	8¾	...
White metal for bearings of machinery ½ bismuth	83½	5½	9½	1
White metal for bearings of engines and machinery	83½	5½	11	...
White metal for bearings of engines and machinery	84	6	10	...
White metal for bearings of engines and machinery	84½	4	11½	...
White metal for bearings of engines and machinery	84½	4½	11	...
White metal for bearings of light machinery . .	85	5	10	...
White metal for bearings of machinery . .	85	6	9	...
White metal for bearings of engines and machinery	86	5½	8½	...
White metal for bearings of engines and machinery	86	6	8	...
White metal for bearings of engines and machinery	87	6	7	...
White metal for bearings of engines and machinery	87	12	...	1
White metal for bearings of machinery ½ bismuth	87½	4	8	...
White metal for general bearings . . .	88½	4	7½	...
White metal for bearings of engines . . .	89	3	8	...
White metal for bearings of engines and machinery	90	2	8	...
White metal for bearings of railway axles . .	90	3	7	...
White metal for large bearings	90½	7½	2	...
White metal for spinning	94	1	5	...

TABLE 77.—MELTING POINTS OF ALLOYS AND METALS, &C., FROM THE EXPERIMENTS OF POUILLET, CLAUDEL, &C., AND FREEZING POINTS OF LIQUIDS, &C.

Tin.	Lead.	Bismuth.	Melts at. Fahr.	Tin.	Lead.	Melts at. Fahr.	Metals, &c.	Melts at. Fahr.
2	3	5	199°	22	4	380°	Platinum . . .	3080°
1	1	4	201°	4	5	390°	Wrought iron .	2912°
3	5	8	212°	8	11	400°	Nickel . . .	2810°
3	7	8	220°	16	25	410°	Steel, maximum .	2552°
3½	8	8	230°	4	7	420°	Steel, minimum .	2372°
5	8	8	240°	8	15	430°	Pure gold . .	2282°
7	8	8	250°	4	8	440°	Cast iron . .	2190°
8	9	8	260°	8	17	450°	Gold coin . .	2156°
8	12	8	270°	4	9	460°	Copper. . .	2050°
8	13	8	290°	4	10	470°	Pure silver . .	1830°
14	14	8	300°	8	23	480°	Bronze . . .	1690°
8	16	8	310°	4	14	490°	Brass . . .	1650°
24	20	8	320°	8	33	500°	Aluminium . .	1300°
24	26	8	330°	4	19	510°	Antimony. . .	810°
8	4	...	340°	4	25	520°	Zinc . . .	773°
10½	4	...	350°	4	30	530°	Lead . . .	620°
13	4	...	360°	5	38	540°	Bismuth . .	507°
17	4	...	370°	4	48	550°	Tin	446°
							Cadmium . .	442°
							Sulphur . . .	239°
							Beeswax, white .	154°
							Beeswax, yellow .	142°
							Stearine . 109° to	120°
							Phosphorus . .	109°
							Tallow . . .	92°
							Oil of turpentine .	14°
							Ice of strong brandy	7°
							1 snow and 1 salt .	0°
							Mercury . .	−39°
							Mercury boils .	662°

Acetic acid congeals at . .	50°	Fahr.
Olive oil " . .	36°	"
Water freezes at . . .	32°	"
Milk " . . .	30°	"
Vinegar " . . .	28°	"
Sea water " . . .	28°	"
Strong wine freezes at . .	20°	"
Mercury congeals at . .	−39°	"
Greatest artificial cold . .	−91°	"
Phosphorous burns . . .	−43°	"

Temperature of Furnaces, &c.—When the fire is at red heat = 1,300; at cherry red heat = 1,700; at orange colour = 2,000; at bright white heat = 2,500; and at a dazzling white heat = 2,800 degrees Fahrenheit. Temperature of the hot blast for melting iron, from 900 to 1,200° F. Welding heat of iron, 2,700° F. Iron is bright red in the dark at 752° F. Iron is red in daylight at 885° F. Metals are red in daylight at 1,077° F. Wrought iron boils at 5000° F.: cast iron at 3,350° F.; sulphur at 570° F.; and phosphorus at 556° F. Temperature of Bessemer furnace, 4,000° F.; puddling furnace, 3,500° F; cupola, 3,000° F.; common fire, 790° F.; of ignition, 637° F.; of common oven, 460° F.; disinfecting chamber for clothing, 240° F.; laundry drying rooms, 110° to 150° F.; of the human body, 98½° F.; and of a comfortable room. 70° F.

Metals when hot are weaker than when cold. Iron loses strength by every increment of heat above 550° F. Copper loses strength by every increment of heat above 32° F., the loss of strength being 5 per cent. at 212°; 20 per cent. at 450°; 30 per cent. at 600°; 50 per cent. at 800°; 75 per cent. at 1100°; and at 1335° it loses all tenacity and becomes a soft viscid mass, although it does not melt until it reaches 2050° F.

Table 78.—SHEWING IN SUCCESSIVE ORDER THE PROPERTIES OF METALS viz.:—Malleability, being beat into thin plates;
Ductility, being drawn into wire;
Tenacity, resistance to pulling asunder.

Malleability.	Ductility.	Tenacity.
Gold.	Gold.	Wrought iron.
Silver.	Silver.	Wrought copper.
Copper.	Platinum.	Platinum.
Tin.	Wrought iron.	Silver.
Cadmium.	Copper.	Gold.
Platinum.	Zinc.	Yellow brass.
Lead.	Tin.	Cast iron.
Zinc.	Lead.	Zinc.
Wrought iron.	Nickel.	Tin.
Nickel.	Palladium.	Bismuth.
Palladium.	Cadmium.	Lead.

SOLDERS.

Table 79.—SOLDERS FOR SOLDERING AND BRAZING.

Soft Solders.	Parts of Tin.	Parts of Lead.	Parts of Bismuth.	Melts at
				Fahr.
Bismuth solder	3	5	3	202°
Bismuth solder	2	2	1	229°
Bismuth solder	2	1	2	236°
Bismuth solder . . .	1	1	1	254°
Bismuth solder	3	3	1	310°
Bismuth solder	4	4	1	320°
Tinman's coarse solder	3	2	...	334°
Tinman's fine solder	2	1	...	340°
Plumber's fine solder	1	2	...	441°
Plumber's coarse solder	1	3	...	482°
Solder for soldering lead	1	1½	...	...
Solder for soldering tin	1	2	...	...
Solder for soldering pewter	2	1	...	...
Soft solder for soldering pewter . .	3	4	2	...
Hard solder for soldering pewter . .	2	1	1	...

Bismuth expands considerably during solidification.

Table 80.—BRAZING SOLDERS FOR BRAZING COPPER, GUN METAL, BRASS, IRON, STEEL, SILVER, AND GOLD.

	Parts of Gold.	Parts of Silver.	Parts of Brass.	Parts of Copper.	Parts of Tin.	Parts of Zinc.	Parts of Antimony.
Soft solder for brazing copper and brass	...	...	...	...	2	...	1
Soft solder for brazing copper and brass	...	...	...	4	1	3	...
Hard solder for brazing copper, gun metal, and brass	...	...	...	1	...	1	...
Harder solder for brazing iron, copper, gun metal, and brass	...	...	...	2	...	1	...
Hardest solder for brazing iron, copper, bronze or gun metal, and brass	...	...	...	3	...	1	...
Another hard solder for brazing copper, gun metal, brass, &c.	...	...	5	...	...	1	...
Silver solder for fine bronze or gun metal and brass work	...	1	...	8	...	8	...
Silver solder for fine bronze or gun metal and brass work	...	1	1	...	...	...	...
Silver solder for German silver and for fine bronze or gun metal	...	5	5	...	...	5	...
Silver solder for steel and for jeweller's and fine work	...	19	1	1	...	...	...
Silver solder for jeweller's and fine work	...	19	10	1	...	...	...
Silver solder for jeweller's, instrument-makers, &c.; very tough and fluid	...	11	...	13	...	...	...
Silver solder for plating	...	2	1	...	...	...	...
Soft silver solder	...	2	1	...	...	...	...
Hard silver solder	...	4	...	1	...	...	...
Gold solder for jeweller's ordinary repairs	3	2	...	1½	...	½	...
Gold solder; fine	12	2	...	4	...	...	...
Gold solder; finer	24	2	...	1	...	...	...
Aluminium solder . . . 6 aluminium	...	...	...	4½	...	89½	...
Aluminium solder . . . 6 aluminium	...	3	...	3	18	9	...
Aluminium solder; soft . . . 6 bismuth	...	...	...	...	94	...	...
Solder for brazing steel	...	...	...	63	...	37	...

In preparing solders, to prevent oxidation, soft solders should be melted under tallow, and hard solders under a thick layer of powdered charcoal.

Fluxes for soldering.—For iron or steel, borax or sal-ammoniac; for tinned iron, resin or chloride of zinc. For zinc, spirits of salts: for lead, tallow, or resin: for lead and tin pipes, and for pewter, resin and sweet oil: for copper, gun-metal, brass, silver, &c., borax or chloride of zinc.: for aluminium, paraffin.

Finishing and Burnishing Gun Metal and other Metals.—It is frequently requisite to give a very high finish to metals: for instance, to prepare them for receiving a coating of silver or nickel-plating. This is accomplished by burnishing the articles on buffs revolving at a high speed, for which purpose the following buffs and burnishing compositions are the best.

Burnishing Bronze, Gun-Metal, Brass, Copper, and White Metal.—The articles, after being well polished with a fine powder, made from old burnt plumbago crucibles, are finely polished by buffing on a leather buff, with rottenstone and oil, or crocus powder and oil, and are then burnished, by buffing with finely-powdered unslacked lime, or dry crocus powder, on a calico buff.

Burnishing Iron and Steel Articles.—The article, after being highly polished with fine emery, is burnished by buffing on a leather buff, first with glass-cutters' sand and afterwards with Trent or finer sand.

Buffs.—Calico buffs are made by cutting a great number of pieces of coarse calico into discs; they are then firmly pressed together, and screwed up on a mandrel, with a nut at each end, between two thick leather discs, with a brass washer at the end of the leather.

Leather buffs are made of a number of discs of walrus hide glued together to the required thickness, and firmly clamped until the glue is set, when they are turned up true, on a mandrel having a nut and washer at each end.

Finishing Brass Work by Acids.—Intricate brass work, which cannot be finished in the ordinary way, is finished in the following manner by acids,—viz., the work is first cleansed by heating and dipping in washing soda and water, and afterwards well rinsed in clean water; it is next plunged for not more than 10 seconds into a solution of water, 1 part, nitric acid, 2 parts; then taken out and plunged, first into clean cold water, and then into hot soap and water, and dried in hot sawdust. Boxwood sawdust is the best, as it does not contain resin.

Clouding Brass.—A solution of charcoal and water is poured on to the surface of highly polished brass, so as to produce circular marks; slate pencil may be used to fill in part of the cloud. The work when dry, is lacquered.

The Weights to the New Imperial Standard Wire-Gauge of sheet-copper, brass, gun-metal, white metal, zinc, and lead are given at pages 310, 311, and the weights of bars of copper, brass, lead, and zinc at page 321.

BLUEING, COLOURING, TINNING, BRONZING, LACQUERING SILVERING AND JAPANNING PROCESSES.

Blueing Iron and Steel Articles.—Fill an iron pan with either clean brass filings, sand, powdered charcoal, or mahogany sawdust; heat the same to a dull red heat, and pass the article through it, in and out, until the required colour is obtained. The article to be well polished, free from grease, and not to be touched with the fingers before inserting. The higher the polish the better will the colour be. For very light articles, such as spectacle frames, hot sawdust is preferable. To take away all traces of grease, the articles should be rubbed with powdered quicklime before blueing.

Blueing Iron and Steel by Boiling.—Place the articles in the following solution, kept at boiling heat. Dissolve 4 oz. hyposulphite of soda in 1½ pints of water, and then add a solution of 1 oz. acetate of lead in 1 oz. of water.

Brown Tint for Iron and Steel.—Dissolve in 4 parts of water, 2 parts of crystallised chloride of iron, 2 parts of chloride of antimony, and 1 part of gallic acid. Apply the solution with a sponge and dry in the air. Repeat the process according to the depth of colour required.

Browning Gun Barrels.—The barrels to be well polished and free from grease, and not to be touched with the hands during the process. First rub with powdered quicklime to remove all trace of grease, then apply with a sponge one of the following solutions:—

Solution No. 1.—Mix in 1 pint of rain water, ⅛ oz. blue-stone; ½ oz muriate tincture of steel; ½ oz. spirits of wine; ⅛ oz. strong nitric acid; ¼ oz. muriate of mercury.

Solution No. 2.—Sulphate of copper, 1 oz.; sweet spirits of nitre, 1 oz.; rain water, 1 pint

Solution No. 3.—Aqua fortis, ½ oz.; sweet spirits of nitre, ½ oz.; tincture of muriate of iron, 1 oz.; spirits of wine, 1 oz.; sulphate of copper, 2 oz.; water, 30 oz.

Solution No. 4.—Tincture of muriate of iron, ½ oz.; spirits of nitric ether, ½ oz.; sulphate of copper, 2 scruples; rain water, ½ pint.

When dry, polish off the rust with a wire scratch brush, and repeat the process until the required depth of colour is obtained. After the last application pour boiling water over the barrels, dry, and while still warm polish with a little beeswax and spirits. *Varnish for gun barrels* after browning: shellac, ½ oz.; dragons' blood, ⅛ oz.; rectified spirits, 1 pint. Warm the barrels before applying.

Browning Iron and Steel Articles.—Immerse in a solution of tincture of iodine, with one half its bulk of water.

Japanning Metal.—A coat of thick coloured varnish, called japan, is laid on to the metal, and dried by baking in a suitable oven, heated to about 300° F. The high temperature evaporates the solvents of the japan, and causes the residue to adhere firmly to the metal. This process is repeated several times until the required depth of colour, and hardness and finish of the surface is obtained. *The varnish* used consists of, methylated spirit, 1 quart; shellac, 4 oz.; resin, 4 oz., dissolved, and coloured with one of the following mixtures: *for black colour*, with ivory black, or with black made of asphaltum, 1 lb.; balsam of copaiba, 1 lb.; melt and thin with hot oil of turpentine. Another black consists of: asphaltum, 3 oz.; boiled linseed oil, 1 gallon; burnt umber, 8 oz.; melt, mix, and thin with hot oil of turpentine. Another black consists of: amber, 12 oz.; asphaltum, 2 oz.; resin, 1 oz.; boiled linseed oil, ½ pint; melt and mix, and when cooling add 1 pint oil of turpentine. *Yellow colour*, king's yellow *White colour*, white lead, ground up with a sixth of its weight of starch; thin with copal varnish,

Iron Lacquer.—Amber, 12 parts; turpentine, 12; resin, 2; asphaltum, 2; drying oil, 6. Another iron lacquer.—Asphaltum, 3 lbs.; shellac, ½ lb.; turpentine, 1 gallon.

Black Finish for Small Articles of Iron and Steel.—Boil 1 part of sulphur in 10 parts of oil of turpentine, paint the article with it thinly, and heat over a spirit lamp until the required depth of colour is obtained.

Tinning Small Articles of Iron, Brass, or Copper by the Boiling Process.—First clean well and pickle in a bath of dilute muriatic acid, and rinse well in fresh clean water; then immerse for a short time, and stir with a zinc rod, in one of the following solutions, which must be boiling hot:—

Solution No. 1.—Ammonia alum, 17¼ oz.; soft water, 12½ lbs.; protochloride of tin, 1 oz.

Solution No. 2.—Bitartrate of potassa, 14 oz.; soft water, 24 oz.; protochloride of tin, 1 oz.; and clean zinc in strips, ½ lb.

Solution No. 3.—Soft water, 1 gallon; grain tin, 2 lbs.; cream of tartar, 1½ lbs.

Tinning Zinc.—Dip in a solution of distilled water, 1 gallon; pyrophosphate of soda, 3¼ oz. fused protochloride of tin, ½ oz.

Galvanizing Iron.—Pickle the articles for 8 hours in water containing 1 per cent. of sulphuric acid, held in a wooden vessel; then scour well, rinse in clean water, and immerse them in a bath of melted zinc, kept covered with a layer of melted sal ammoniac to prevent oxidation of the zinc.

Black Finish for Brass.—Dissolve copper wire in nitric acid, add 3 parts of water to one of the acid, make the article hot and dip it in the solution; then heat the article over a spirit lamp until the desired depth of colour is obtained, and give one coat only of lacquer.

Black Finish for Brass.—Reduce nitrate of copper to the oxide, warm the metal slightly and apply with a brush, and then heat the article until the required depth of colour is obtained.

Black Finish for Brass.—Make a strong solution of nitrate of silver in one dish, and of nitrate of copper in another; mix the two together and plunge the brass into it; remove and heat the brass evenly, until the required depth of colour is obtained.

Black Finish for Brass.—Another way is to immerse the brass until it turns black in a mixture of:—white arsenic, ½ lb.; sulphate of iron, ½ lb.; hydrochloric acid, 6 lbs.; when the required depth of colour is obtained, rinse well in water, dry in sawdust, polish with black lead, and lacquer. In some cases brass is simply blackened by laying on a mixture of vegetable black and french polish.

Another way to blacken brass is, first to polish it with tripoli, then wash it with a mixture of 1 part of nitrate of tin and 2 parts of chloride of gold; allow this wash to remain for nearly a quarter of an hour, and wipe off with a linen cloth.

Bronzing Brass, Copper, and other Metals.—Copper bronze:—fuchsin, 10 parts; aniline purple, 5 parts; methylated spirit, 100 parts; heat, and, when solution takes place, add benzoic acid, 5 parts; next boil the whole for 10 minutes, or until the colour of the mixture changes to bronze colour.

Antique Bronze can be imitated by using the following mixture:—muriate of ammonia, or sal ammoniac, ¾ oz.; salts of tartar, or carbonate of potash, 1½ drachms; vinegar, 1 quart. Apply with a sponge and repeat several times until the proper tint is obtained. Brown, and every shade to black: use a mixture of 5 drachms nitrate of iron in 1 pint of water. Chocolate colour is obtained by steeping iron wire in aqua fortis for a quarter of an hour before dipping; then dip the brass in the same.

Chinese Bronze.—Powder and make into thin paste with vinegar, vermilion, 2 oz.; verdigris, 2 oz.; alum, 7 oz.; sal ammoniac, 5 oz.; after using, gently warm the article; afterwards wash and dry, and repeat the process until the required tint is obtained. By adding a little blue vitriol to this mixture a chestnut brown is obtained, and a little borax gives a yellow tint.

Lacquering.—This process is varnishing metals to protect their colour. The work is first thoroughly cleaned, and then pickled for two hours in a pickling solution of 3 parts water and 1 part nitric acid, contained in an earthenware vessel, and afterwards scoured with fine sand and water, applied with a brush.

Dipping Brass.—After pickling, the work is dipped for 3 seconds in pure nitric acid, and afterwards instantly plunged into a solution of whiting and water, or of water and common washing soda, which removes the acid, and the work comes out a fine gold colour; next dry and lacquer. The work should be held with tongs made of brass, when dipping. The lacquer to be warmed and applied with a camel's hair brush to the work, which should be previously heated to 212°.

Dissolving Metals.—Copper, bismuth, nickel and zinc, dissolve in nitric acid. Lead and antimony, dissolve in a solution of nitric acid, 1 part; hot water, 2 parts. Tin dissolves in hydrochloric acid.

Table 81.—COMPOSITION OF LACQUERS.

		Strong Simple.	Pale Simple.	Fine Pale.	Pale Gold.	Bright Gold.	Deep Gold.	Pale Yellow.	Red.	Tin Lacquer.	Green for Bronze.
Shellac	ounce	4	1	1	2	8	3	2	—	15	—
Mastic	drachm	—	—	—	—	—	—	—	—	30	—
Canada balsam . .	drachm	—	—	—	—	—	—	—	—	30	—
Spirits of wine . .	pint	1	1	1	2	4	1	1	—	6	—
Simple pale lacquer .	pint	—	—	—	—	—	—	—	1	—	1
Dragon's blood . .	drachm	—	—	—	1	—	4	—	8	20	—
Annatto	drachm	—	—	—	8	1	—	—	32	—	—
Turmeric	drachm	—	—	1	32	4	16	—	—	60	4
Gamboge	drachm	—	—	1	—	—	—	2	—	—	1
Saffron	drachm	—	—	2	—	1	—	—	—	10	—
Cape aloes	drachm	—	—	—	—	—	—	4	—	—	—
Sandarac	drachm	—	—	—	8	—	—	—	—	—	—

To remove lacquer from brass, boil for 20 minutes in a solution of water, 1 gallon; potash, ½ lb.; withdraw and plunge into cold water.

Silvering Brass, Iron, and other Metals.—First clean and pickle the articles in the same way as for tinning, as given above, then immerse them for a few seconds in a solution of cyanide of silver. Another process is: heat 1 oz. nitric acid until it boils, then add a few pieces of silver; as soon as they are dissolved add a handful of common salt to kill the acid, then make it into a paste with whiting, and apply with water and wash leather. Another process is: mix 1 part of dry chloride of silver, finely powdered, with 3 parts of pearl ash, 1 part of chalk, and 1½ parts common salt; rub on with water and wash leather.

Gilding Brass, Bronze, and Other Metals.—Apply the following mixture at boiling heat:—cyanide of potass, 2½ lb.; carbonate of potass, 5 oz.; cyanate of potass, 2 oz.; the whole diluted in 5 pints of water, containing in solution ¼ oz. chloride of gold; and afterwards varnish the gilt surface.

To Whiten Silver.—Boil in a solution of:—1 part cream of tartar; 2 parts common salt, and 50 parts water.

To Dead-Whiten Silver.—Boil in a solution of alum and water until the desired tint is obtained, and wash well with a brush in hot water with soap and carbonate of soda.

Silver Paint.—Gum lac is dissolved in 4 times its volume of alcohol, and to this thick solution, silver powder is added, in the proportion of 1 part powder to 3 of the solution. The surface to be coated, is covered with spanish white, the metallic mixture is applied with a brush, and when dry, is burnished with a steel or stone burnisher. Bronze gold, or any other metal powder, may be used in the same way.

Whitening Brass.—Make a mixture of 2 lbs. grain tin, 1½ lb. cream of tartar, and 1 gallon of water; boil and immerse the brass for a few minutes at a boiling temperature.

Frosting Silver.—Apply with a brush, a solution of water half a pint; cyanide of potassium, 1 ounce.

Lacquer Varnish for Colouring Metals.—Mix turmeric and annatto, with lac varnish, to the required depth of colour.

Zinking, or Coating Small Articles with Zinc.—First clean and pickle, next dip the articles in a mixture of zinc dissolved in hydrochloric acid, to which a little sal ammoniac is added; then dry and dip in melted zinc and shake off the superfluous metal.

Coppering or Bronzing Iron and Steel Articles.—Clean and immerse in a solution of sulphate of copper, 3½ oz.; sulphuric acid, 3½ oz.; water, 1 gallon.

Tinning Iron and Steel.—Clean and immerse in hot oil or tallow, and then immediately dip into melted tin.

Moire Metal.—Clean and heat the tin over a clear fire, until water will fizz on its surface; then dip it quickly into a mixture of—water, 4 parts; muriatic acid, 1 part; nitric acid, 1 part; rinse in water, dry quickly in hot sawdust, and varnish while hot.

HARDENING, SOFTENING, AND TEMPERING PROCESSES.

Case-hardening Wrought-Iron.—Pack the articles to be hardened, in a box, filled to the top with small pieces of bone and wood charcoal, and a few pieces of burnt leather, the heaviest articles to be placed at the bottom of the box. Make the lid of the box tight, with a lute of equal parts of clay and sand. Subject for 10 hours to a red heat in a furnace, and quench the articles in water.

NOTE.—Articles to be case-hardened before placing in the box, should have the threads of screws and nuts, and other parts which require to be left soft, plugged with clay.

Hardening Wrought-Iron with Potash.—This process only hardens to a very slight depth. Heat the article to a bright red, rub the surface well over with powdered prussiate of potash, or with a mixture of 3 of prussiate of potash, to 1 of sal ammoniac reduced to powder, and allow it to cool to a dull red, then quench in water. By repeating the process, a slightly deeper hardening will be obtained, but it is much inferior to case-hardening.

To harden Malleable Cast-Iron.—Heat the article to a bright red, rub the surface well over with a mixture of equal parts of potash, saltpetre, and sulphate of zinc, allow it to cool to a dull red, and quench in water.

To harden Cast-Iron.—Heat the article to a bright red, and quench in a mixture of 3 gallons of water, ½ pint oil of vitriol, and 2 oz. saltpetre.

Another mixture for quenching consists of salt water 10 gallons, salt 1 peck, oil of vitriol ½ pint, saltpetre ½ lb., prussiate of potash ¼ lb., cyanide of potash ½ lb,; by repeating the process cast-iron may be made harder.

To harden Cast-Iron.—Another process is to heat to bright red, and rub the surfaces with a mixture of equal parts powdered prussiate of potash, saltpetre and sal ammoniac. Allow the article to cool to red heat and quench in a mixture—4 oz. sal-ammoniac and 2 oz. prussiate of potash per gallon of water.

To anneal or soften Finished Iron or Steel Work.—Lute an iron box with clay, and place the articles in the box, full of turnings or borings, of the same metal as the articles are made of. Make the lid of the box tight with a lute of clay. Heat slowly to a red heat in a furnace, and let the fire die out.

To soften Steel Forgings, &c.—Heat to a low red heat, and cool in lime or whiting.

To soften Steel Forgings, or Hard Steel or Iron.—Another process is to pack the articles in a box full of whiting or iron borings, make the lid of the box tight with a lute of clay, heat to a low red heat in a furnace for 4 hours and let the fire die out.

To drill Hard Steel.—Heat the drill in a charcoal fire, and quench in mercury. Moisten the work when drilling with a mixture of turpentine and camphor.

To soften Chilled Cast-Iron.—Heat the article to nearly white heat, and cover it with a good depth of small coal, and let it remain until cold.

To soften small Castings of hard Cast-Iron.—Pack them in a box of fine coke screenings, put a thin layer of fine sand on the top well damped, heat in a furnace to a low red heat and let the fire die out; or they may be softened to a slight depth by steeping for 24 hours in 1 part aqua fortis to 4 parts of water.

Malleable Cast-Iron.—The articles are first cast in cast iron, and malleableised,—by burning off the carbon combined with the iron from which the castings were made,—by a process of annealing. The iron used is a white hematite metal, No. 5 brand, which contains little carbon. The castings are first cleaned, and then packed into iron boxes, with alternate layers of either fine iron scales from rolling mills, or powdered hematite ore. The boxes are closed at the top with a mixture of sand and clay, and are next placed in an annealing oven, where they are kept under an equable red heat for from 7 to 14 days if the castings are light, and for about 21 days if they are heavy.

Welding Cast-Steel.—Mix borax 10 parts, sal ammoniac 1. Simmer over fire for 1 hour, or until clear, pour out, cool, and reduce to powder. Heat the steel in a coke fire, to bright yellow heat.

Welding Cast-Steel.—Another mixture is, powdered limestone 6 parts, sulphur 1 part; and another mixture is, borax 10 parts, sal-ammoniac 2, sulphur 1 part.

Restoring slightly burnt Cast-Steel.—Borax, 1½ lb.; sal-ammoniac, ½ lb.; prussiate of potash, ¼ lb.; resin, 1 oz.; powder and mix with 1 gill each of water and alcohol. Boil for a short time to a paste, dip the hot steel in the mixture, and slightly hammer.

To distinguish Steel from Iron.—Nitric acid does not affect iron, but produces a black spot on steel. The darker the spot the harder the steel.

To harden Hammers and other Tools.—Bone dust, 2 parts; common salt, 3; burnt leather shreds, 1; prussiate of potash, 1 part. Heat to a cherry red and plunge into this compound.

To harden a Drill to drill Glass.—Heat to cherry red, and quench in mercury: when drilling moisten with turpentine and a little camphor.

To soften Copper and Brass, Gold and Silver.—Heat to a low red heat, and quench in a solution of salt and water.

Hardening Steel Tools.—To obtain the best results, the steel should be heated in a charcoal fire. Heat to a cherry red, and dip about an inch deep in tepid water, rub the hardened portion with a piece of sandstone, the heat in the uncooled portion will be quickly transferred to the point just cooled, and by watching the colour any degree of temper may be obtained. *Chisels* for chipping iron, should be tempered, or lowered to a dark straw colour; *turning tools* for wrought iron, to a pale straw colour; *turning tools* for cast iron, should be made as hard as water will make them; *shear blades and punches* should be lowered to light purple colour; *turning tools* for brass, to a straw colour; *turning tools* for wood, to a dark straw colour; *taps and dies, rhymers and circular cutters for milling and wheel cutting machines*, each to a light brown colour.

To harden Trowels, Saws and various Steel Articles.—Quench in one of the following mixtures:—

Mixture No. 1.—Sperm oil, 1 gallon; tallow, 1 lb.; neats' foot oil, ½ pint; pitch, 1 oz.; black resin, 3 oz.; melted, mixed and cooled.

Mixture No. 2.—Sperm oil, 1 gallon; tallow, 2 lb.; wax, ¼ lb. This mixture is only suitable for very small steel articles.

Mixture No. 3.—Sperm oil, 1 gallon; tallow, 2 lb.; wax, ¼ lb.; resin, 1 lb.

Mixture No. 4.—Sperm oil, 20 gallons; tallow, 20 lb.; ox foot oil, 10 gallons; pitch, 1 lb.; resin, 3 lb.

Melt the pitch and resin before adding the other ingredients. Mix and heat the whole in an iron pot; when sufficiently heated it will catch fire when a light is held near it. The flame is put out by placing a lid on the pot. These mixtures make the steel very hard and brittle; and to temper the same, wipe a portion only of the composition off when the article is withdrawn from the bath, then hold it over a coke fire till the grease ignites, and blaze off a small portion only if the article is required to be hard, and a larger amount if required to be softer.

Hardening Tools and Cutters.—Tools when heated to a cherry red and quenched in one of the following solutions are less liable to crack, and give better results, than when quenched in water.

Hardening Solution No. 1.—Soft warm water, 1 gallon; salt, ½ pint.

Hardening Solution No. 2.—Make a solution of water, salt, and nitrate of iron. Keep at 60 degrees temperature.

Hardening Solution No. 3.—To 1 bucketful of water, add 1 gill vitriol.

Hardening Solution No. 4.—To 1 bucketful of water, add a handful of slaked lime.

Hardening Solution No. 5.—To 3 gallons rain water, add 3 oz. spirits of nitre, 3 oz. hartshorn, 3 oz. white vitriol, 3 oz. sal-ammoniac, 3 oz. alum, 6 oz. salt, 2 handfuls of shreds of leather partly burnt; this solution is used for hardening chisels, for dressing French burr stones.

To harden Chisels for cutting Granite and Marble.—Heat to a cherry red and quench in a mixture of whale oil, 1 gallon; resin, 2 lb.; beeswax, 1 lb.; melted and mixed.

To harden Gravers and Drills for cutting very hard materials.—Heat to cherry red, and quench in one of the following:—1st. Mercury; 2nd. Plunge into sealing wax, withdraw quickly, plunge in a fresh place and repeat the process until the drill is cold; 3rd. Plunge repeatedly into either yellow soap, or beeswax, until the drill is cold; 4th. Drive repeatedly into lead, until the drill is cold.

Hardening Steel Spiral Springs.—Spiral springs may be heated in a melted alloy, composed of 12 parts lead and 1 tin, until they are of the same temperature as the alloy (which should be just fluid), or they may be placed inside a gas pipe and heated in a fire, the pipe should be turned round frequently in the fire until they are uniformly heated to a cherry red; long springs should be placed on a mandrel before heating, otherwise they are liable to bend and become irregular in the coils; slight springs should be quenched in oil; medium thick springs in hot water about 60 degrees temperature, with a film of oil on the top of the water; and thick springs in water only, heated to 70°. Always plunge the spring endways, and do not take out until quite cold.

To temper Springs.—Smear them over with a composition of sperm oil, 1 gallon; rendered beef suet, 1 lb.; neatsfoot oil, 1 gill; resin, ¼ lb.; heat uniformly by holding them inside a hot pipe until the grease burns uniformly upon all parts and the grease burns off with a blaze; if the grease on the ends takes fire sooner than that on the middle, cool the same with grease and blaze again. Thick springs require to be repeatedly dipped in the grease and blazed, and unless the blazing is uniform the temper will not be uniform. When the blazing is finished and a uniform blue colour is obtained, finally quench in oil.

Tempering Steel Tools.—When steel is hardened to the hardest degree, as at the first quenching, it is comparatively weak and brittle, and to strengthen the steel it is necessary to lower the degree of hardness by re-heating, during which process as the temperature rises, the polished surface assumes various shades of colour, which indicate various degrees of temper, and the colours change successively according to the following table; when the desired colour is reached the tool is then quenched.

Table 82.—TEMPERATURE FOR TEMPERING STEEL TOOLS.

Temper Colour.	Description of Tools.	Temperature.	ALLOY WHOSE FUSING POINT IS OF THE SAME TEMPERATURE.	
		Fahr.	Tin.	Lead.
Very faint yellow .	Lancets and instruments . .	420°	4	7
Pale straw yellow	Turning tools for metal . . .	430°	8	15
Straw yellow . .	Razors	450°	8	17
Dark straw yellow or orange . .	Penknives and chipping chisels for hard cast iron . . .	470°	4	10
Light brown . .	Taps and dies; rhymers; shears and scissors	490°	4	14
Brown yellow . .	Hatchets; chipping chisels; and other percussive tools . . .	500°	8	33
Red	Carpenter's tools in general .	510°	4	19
Light purple . .	Saws; shear blades and punches	520°	4	25
Dark purple . .	Fine watch springs and table knives	530°	4	30
Bright blue . .	Swords and lock springs . .	550°	4	48
Full blue . . .	Daggers; fine saws; and needles	560°		
Darker Blue . .	Springs and augers . . .	570°		
Dark blue . . .	Soft, for common saws . .	600°		

Tempering by the Thermometer.—Put the articles to be tempered into a vessel containing sufficient oil, or tallow, or sand to cover them (or use one of the alloys given in the above table), then heat the whole uniformly to the required degree of heat (shown by a suitable thermometer) corresponding to the hardness required, then withdraw and quench. If no thermometer is available, and oil or tallow is used, these begin to smoke at 430°—or pale straw yellow—and go out when the light is withdrawn at 570° or darker blue of the above table.

The degree of Temper which a tool will take depends upon the proportion of carbon contained by the steel. The following is the usual percentage of carbon in steel:—

Description of Steel.	Carbon per cent.	Description of Steel.	Carbon per cent.
Surgical instruments . .	1·48	Carpenter's tools; cutters .	1·10
Razors	1·45	Chisels and hatchets . .	1·00
Tool steel for chilled rolls .	1·40	Shears; setts and springs .	·80
Saw files; gravers, &c. . .	1·35	Forgings for shafts, &c. .	·50
Tools for cutting very hard metals	1·30	Steel rails	·40
		Forgings for shafts; tyres	·33
Tools for cutting metals .	1·25	Ship plates and boiler plates . . .	·17
Shears; cutlery, files . .	1·20		
Smiths' tools; dies, &c. .	1·15	Boiler plates . . .	·15

HARDENING AND TEMPERING TAPS, RHYMERS AND CUTTERS.

The quality of Steel being much improved by hammering, taps, rhymers, and cutters should be forged to the proper size, to allow for turning. Steel of medium grain should be used, and they should not be softened with their skin on, otherwise they will warp when hardened, owing to the tension caused by forging; to remove the tension, they should be roughly turned all over, before softening them. The process of softening equalises the grain of the metal, and is best performed, by enclosing the taps and rhymers in a piece of wrought-iron gas-tubing, filled with wrought-iron turnings, the ends of the tube being plugged up with clay; the tube is then made red hot, and is allowed to cool slowly, by leaving it covered up with hot ashes for 12 hours.

To harden Taps.—First slightly warm and rub them all over, with a mixture of Castile soap and lamp black, which preserves the edges from being burnt, then place them in a wrought iron pipe, say $\frac{3}{4}$ inch thick, filled with charcoal dust, plug the ends of the tube with clay, and heat it uniformly by turning it round occasionally in the furnace, until it comes to a cherry red heat, then carefully withdraw it from the furnace, knock the plug out of one end of the tube, and drop the contents vertically, into a solution heated to 60°, of 1 gallon rain water; 1 lb. salt; and allow them to remain therein, until they become quite cold: if they are taken out of the water during cooling they are liable to crack. Care should be taken to keep the taps perpendicular when in the water, as if allowed to fall sideways they will warp.

To temper Taps.—After hardening, polish and then temper as follows:—A wrought iron hoop—of a diameter inside, equal to double the diameter of the tap—and in thickness, not less than the diameter of the tap,—and in depth, about one-half the length of tap,—should be uniformly heated to a cherry red heat, then warm the jaws of a pair of tongs, and hold the square of the tap in the tongs, and pass the tap right through the hoop, leaving only the square part of the tap inside the hoop. The tap should then be turned slowly round, until that end becomes slightly heated; the shank and the screw part should then be moved slowly backwards and forwards through the hoop, and at the same time turned slowly round, until evenly coloured, and when it reaches a light brown colour, the tap should be quenched perpendicularly in oil. The square end of the tap, should be lowered to a deeper colour than the screw part.

To harden and temper Rhymers.—Proceed the same way as for taps; or they may be heated in molten lead and quenched in the same solution as the taps; the advantage of heating them in molten lead, is, that the outside can be properly heated, before the metal at the centre is red hot, and the metal at the centre will be sufficiently soft, to allow of the rhymer being straightened after hardening; should it have warped during hardening, to straighten it, lay it on a block of lead with the arched side upwards, place a copper drift in the uppermost flute, and strike the same with a hammer.

To harden Circular Cutters for milling machines and wheel-cutting machines, and similar cutters, having a hole through the centre. It is necessary when quenching, to prevent the water from getting to the centre of the hole too soon, otherwise it will cool more rapidly than the body of the cutter, and will crack; to prevent this, protect the hole with a bolt and two turned washers; the bolt should be less than the diameter of the hole, and the washers should be moderately tightened. In cases where it is not convenient to use a bolt and washers, the hole should be plugged with a mixture of clay and finely sifted iron borings. Then warm the cutter slightly and rub the cutting edges over, with a mixture of Castile soap and lamp black, and heat it in a charcoal fire, to a uniform cherry red heat, and quench it edgeways in a solution of 1 gallon of rain water and 1 lb. of salt. To temper these cutters hold them over a piece of hot iron, until they arrive at a light brown colour, and quench in oil. In preparing these and all kinds of cutters, they should be turned before annealing, and they should neither be straightened nor bent after annealing.

The Quality of Cutting Tools of all kinds depends greatly upon their treatment in forging, as well as in hardening and tempering.

If steel be either overheated, heated too frequently, or worked at too high a temperature, it becomes more or less decarbonised, and deteriorated in quality. In forging a tool, it should not be heated above a light cherry-red, and it should be quickly and lightly hammered until nearly black. All kinds of cutting tools are improved in quality and durability by light hammering at a low heat.

Cracks and incipient flaws are liable to be developed in steel during the process of hardening, if heated too highly before quenching; if improperly quenched; if taken out of the water before it is cold; or if tempered in cold water. The chill should always be taken off water before it is used for hardening or tempering steel.

Table 82A.—NUMBER OF THREADS, DIAMETER AND PITCH IN MILLIMETRES OF THE BRITISH ASSOCIATION GAUGE FOR APPARATUS-SCREWS.

Number.	Threads per Inch.	DIMENSIONS IN MILLIMETRES.		Number.	Threads per Inch.	DIMENSIONS IN MILLIMETRES.	
		Diameter.	Pitch.			Diameter.	Pitch.
25	353	·25	·07	12	90·7	1·3	·28
24	317	·29	·08	11	81·9	1·5	·31
23	285	·33	·09	10	72·6	1·7	·35
22	259	·37	·10	9	65·1	1·9	·39
21	231	·42	·11	8	59·1	2·2	·43
20	212	·48	·12	7	52·9	2·5	·48
19	181	·54	·14	6	47·9	2·8	·53
18	169	·62	·15	5	43·0	3·2	·59
17	149	·70	·17	4	38·5	3·6	·66
16	134	·79	·19	3	34·8	4·1	·73
15	121	·90	·21	2	31·4	4·7	·81
14	110	1·0	·23	1	28·2	5·3	·90
13	101	1·2	·25	0	25·4	6·0	1·00

Table 83.—PROPORTIONS OF ENGINEERS' HAND-WORKING TAPS, WHITWORTH'S THREAD.

Diameter of Tap in Inches.	Full Length of Tap from End to End in Inches.	Length of Screw Part in Inches.	Diameter at Bottom of Thread in Inches.	Diameter of Shank in Inches.	Size of Square in Inches.	Length of Square in Inches.	Pitch in Parts of an Inch.	Number of Threads per Inch.	CHANGE WHEELS TO BE USED FOR CUTTING THE SCREW OF TAP, WITH A LATHE HAVING A LEADING SCREW OF ½ INCH PITCH.			
									Lathe Spindle.	Leading Screw.	Intermediate Stud Wheel.	Stud Pinion.
1/16	1 1/2	5/8				3/16	1/60	60	10	90	50	15
3/32	1 5/8	3/4				3/16	1/48	48	10	90	40	15
1/8	1 3/4	7/8				1/4	1/40	40	20	125	80	25
5/32	1 7/8	7/8				1/4	1/32	32	20	100	80	25
3/16	2	1				5/16	1/24	24	20	90	80	30
7/32	2 1/8	1 1/16				5/16	1/24	24	20	90	80	30
1/4	2 1/4	1 1/8	3/16	3/16		3/8	1/20	20	40	100	80	20
5/16	2 1/2	1 3/8	1/4	1/4	5/32	7/16	1/18	18	40	90	80	20
3/8	2 3/4	1 1/2	9/32	9/32	7/32	1/2	1/16	16	45	90	80	20
7/16	3 1/4	1 3/4	11/32	11/32	9/32	1/2	1/14	14	20	140		
1/2	3 1/2	2	13/32	13/32	5/16	9/16	1/12	12	20	120		
9/16	3 3/4	2 1/8	15/32	15/32	5/16	9/16	1/12	12	20	120		
5/8	4	2 1/4	17/32	17/32	3/8	5/8	1/11	11	20	110		
11/16	4 1/4	2 3/8	9/16	9/16	3/8	11/16	1/11	11	20	110		
3/4	4 1/2	2 1/2	5/8	5/8	7/16	3/4	1/10	10	20	100		
13/16	4 3/4	2 5/8	11/16	11/16	7/16	3/4	1/10	10	20	100		
7/8	5	2 7/8	23/32	23/32	1/2	13/16	1/9	9	20	90		
15/16	5 1/4	3	25/32	25/32	1/2	13/16	1/9	9	20	90		
1	5 1/2	3 1/4	27/32	27/32	5/8	7/8	1/8	8	20	80		
1 1/8	6	3 1/2	15/16	15/16	11/16	1	1/7	7	20	70		
1 1/4	6 1/2	3 3/4	1 1/16	1 1/16	13/16	1 1/8	1/7	7	20	70		
1 3/8	7 1/2	4 1/4	1 5/32	1 5/32	13/16	1 1/8	1/6	6	20	60		
1 1/2	8	4 3/4	1 9/32	1 9/32	1	1 1/4	1/6	6	20	60		

NOTE.—Hand-working master taps are made larger in diameter than ordinary taps, to the extent of twice the depth of the thread, the bottom

Table 83 *continued*.—PROPORTIONS OF ENGINEERS' HAND-WORKING TAPS, WHITWORTH THREAD.

Diameter of Tap in Inches.	Full Length of Tap from End to End in Inches.	Length of Screw Part in Inches.	Diameter at Bottom of Thread in Inches.	Diameter of Shank in Inches.	Size of Square in Inches.	Length of Square in Inches.	Pitch in Parts of an Inch.	Number of Threads per Inch.	CHANGE WHEELS TO BE USED FOR CUTTING THE SCREW OF TAP, WITH A LATHE HAVING A LEADING SCREW OF $\frac{1}{2}$ INCH PITCH.		
									Lathe Spindle.	Leading Screw.	
$1\frac{5}{8}$	$8\frac{1}{2}$	$5\frac{1}{4}$	$1\frac{11}{32}$	$1\frac{11}{32}$	1	$1\frac{1}{4}$	$\frac{1}{5}$	5	20	50	of the thread of master taps being the same diameter as that of the top of the thread of ordinary taps.
$1\frac{3}{4}$	9	$5\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{8}$	$1\frac{3}{8}$	$\frac{1}{5}$	5	20	50	
$1\frac{7}{8}$	$9\frac{1}{2}$	$5\frac{3}{4}$	$1\frac{19}{32}$	$1\frac{19}{32}$	$1\frac{1}{8}$	$1\frac{3}{8}$	$\frac{2}{9}$	$4\frac{1}{2}$	40	90	
2	10	6	$1\frac{23}{32}$	$1\frac{23}{32}$	$1\frac{5}{16}$	$1\frac{1}{2}$	$\frac{2}{9}$	$4\frac{1}{2}$	40	90	
$2\frac{1}{8}$	$10\frac{1}{2}$	$6\frac{1}{4}$	$1\frac{27}{32}$	$1\frac{27}{32}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$\frac{2}{9}$	$4\frac{1}{2}$	40	90	
$2\frac{1}{4}$	11	$6\frac{3}{4}$	$1\frac{15}{16}$	$1\frac{15}{16}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$\frac{1}{4}$	4	40	80	
$2\frac{3}{8}$	$11\frac{1}{2}$	$7\frac{1}{4}$	$2\frac{1}{32}$	$2\frac{1}{32}$	$1\frac{5}{8}$	$1\frac{5}{8}$	$\frac{1}{4}$	4	40	80	
$2\frac{1}{2}$	12	$7\frac{3}{4}$	$2\frac{3}{16}$	$2\frac{3}{16}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$\frac{1}{4}$	4	40	80	
$2\frac{5}{8}$	$12\frac{1}{2}$	$8\frac{1}{4}$	$2\frac{5}{16}$	$2\frac{5}{16}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$\frac{1}{4}$	4	40	80	
$2\frac{3}{4}$	13	$8\frac{3}{4}$	$2\frac{3}{8}$	$2\frac{3}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	$\frac{2}{7}$	$3\frac{1}{2}$	40	70	
$2\frac{7}{8}$	$13\frac{1}{2}$	$9\frac{3}{4}$	$2\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{7}{8}$	$1\frac{7}{8}$	$\frac{2}{7}$	$3\frac{1}{2}$	40	70	
3	14	$10\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{5}{8}$	2	2	$\frac{2}{7}$	$3\frac{1}{2}$	40	70	

Table 84.—WHITWORTH'S THREAD FOR LARGE TAPS.

Size of Tap, in inches . .	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{3}{4}$	6
Number of threads per inch .	$3\frac{1}{4}$	$3\frac{1}{4}$	3	3	$2\frac{7}{8}$	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{1}{2}$

Table 85.—MACHINE WORKING TAPS FOR TAPPING NUTS, WHITWORTH'S THREAD.

Diameter of tap, in inches	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{8}$	$2\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$	3
Full length of tap, from end to end, in inches . .	$5\frac{1}{2}$	6	$6\frac{1}{2}$	7	8	9	$9\frac{1}{2}$	10	11	12	13	$13\frac{1}{2}$	14	15	16	$16\frac{1}{2}$	17	18	19	$19\frac{1}{2}$	20	21
Length of screw part, in inches	$2\frac{1}{2}$	3	$3\frac{1}{4}$	$3\frac{3}{4}$	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{2}$	6	$6\frac{1}{2}$	$6\frac{3}{4}$	7	$7\frac{1}{4}$	$7\frac{1}{2}$	8	$8\frac{1}{2}$	9	$9\frac{1}{2}$	10	11	12

NOTE.—The other proportions are the same as for hand-working taps.

Table 86.—PROPORTIONS OF GAS TAPS (WHITWORTH'S GAS SCREW-THREAD).

Internal Diameter of Pipe.	Diameter of Tap. Also the External Diameter of the Pipe.	Diameter at the Bottom of Thread.	Number of Threads per Inch.	CHANGE WHEELS TO BE USED FOR CUTTING THE SCREW OF TAP, WITH A LATHE HAVING A LEADING SCREW OF ½ INCH PITCH.				Internal Diameter of Pipe.	Diameter of Tap. Also the External Diameter of the Pipe.	Diameter at the Bottom of Thread.	Number of Threads per Inch.
				Lathe Spindle.	Leading Screw.	Intermediate Wheel.	Stud Pinion.				
Inches.	Inches.	Inches.						Inches.	Inches.	Inches.	Inches.
$\frac{1}{8}$	·3825	·3367	28	20	120	70	30	$1\frac{5}{8}$	2·021	1·9045	11
$\frac{1}{4}$	·518	·4506	19	50	100	95	20	$1\frac{3}{4}$	2·047	1·9305	11
$\frac{3}{8}$	·6563	·5889	19	50	100	95	20	$1\frac{7}{8}$	2·245	2·1285	11
$\frac{1}{2}$	·8257	·7342	14	20	140			2	2·347	2·2305	11
$\frac{5}{8}$	·9022	·8107	14	20	140			$2\frac{1}{4}$	2·5875	2·471	11
$\frac{3}{4}$	1·041	·9495	14	20	140			$2\frac{1}{2}$	3·0013	2·8848	11
$\frac{7}{8}$	1·189	1·0975	14	20	140			$2\frac{3}{4}$	3·247	3·1305	11
1	1·309	1·1925	11	20	110			3	3·485	3·3685	11
$1\frac{1}{8}$	1·492	1·3755	11	20	110			$3\frac{1}{4}$	3·6985	3·582	11
$1\frac{1}{4}$	1·65	1·5335	11	20	110			$3\frac{1}{2}$	3·912	3·7955	11
$1\frac{3}{8}$	1·745	1·6285	11	20	110			$3\frac{3}{4}$	4·1255	4·009	11
$1\frac{1}{2}$	1·8825	1·766	11	20	110			4	4·339	4·2225	11

Table 87.—PROPORTIONS OF RHYMERS.

	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
Diameter of rhymer	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$
Full length of rhymer, end to end .	5	$5\frac{1}{2}$	6	$6\frac{1}{2}$	7	$7\frac{1}{2}$	8	$8\frac{1}{2}$	9	$9\frac{1}{2}$	10	$10\frac{1}{2}$	11	$11\frac{1}{2}$	12	13
Length of cutting part	$3\frac{3}{8}$	$3\frac{5}{8}$	4	$4\frac{3}{8}$	$4\frac{3}{4}$	5	$5\frac{1}{2}$	$5\frac{3}{4}$	6	$6\frac{1}{2}$	$6\frac{3}{4}$	7	$7\frac{1}{2}$	$7\frac{3}{4}$	8	$8\frac{1}{4}$
Diameter of shank	$\frac{3}{32}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{13}{32}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Size of square			$\frac{5}{32}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{15}{32}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$
Length of square			$\frac{7}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{7}{8}$	1
Length of taper part from cutting end	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{1}{2}$
Diameter of cutting end . . .	$\frac{7}{32}$	$\frac{9}{32}$	$\frac{5}{13}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{15}{16}$	$1\frac{1}{16}$	$1\frac{3}{16}$	$1\frac{9}{32}$	$1\frac{13}{32}$

Table 88.—WHITWORTH'S STANDARD SCREW-THREADS FOR GAS, WATER, AND HYDRAULIC IRON PIPING.

GAS AND WATER PIPING.

Internal Diameter of Pipe.	External Diameter of Pipe.	Number of Threads per Inch.
Inches.	Inches.	
1/8	·385	28
1/4	·520	19
3/8	·665	19
1/2	·822	14
3/4	1·034	14
1	1·302	11
1 1/8	1·492	11
1 1/4	1·650	11
1 3/8	1·745	11
1 1/2	1·882	11
1 5/8	2·021	11
1 3/4	2·047	11
1 7/8	2·245	11
2	2·347	11
2 1/8	2·467	11
2 1/4	2·587	11
2 3/8	2·794	11
2 1/2	3·001	11
2 5/8	3·124	11
2 3/4	3·247	11
2 7/8	3·367	11
3	3·485	11
3 1/4	3·698	11
3 1/2	3·912	11
3 3/4	4·125	11
4	4·339	11

HYDRAULIC PIPING.

Internal Diameter of Pipe.	External Diameter of Pipe.	Pressure in lbs. per Square Inch.	Number of Threads per Inch
Inches.	Inches.		
1/4	5/8	4000	14
1/4	3/4	6000	14
1/4	7/8	8000	14
1/4	1	10000	14
3/8	3/4	4000	14
3/8	7/8	6000	14
3/8	1	8000	14
3/8	1 1/8	10000	14
1/2	1	4000	14
1/2	1 1/8	6000	14
1/2	1 1/4	8000	11
1/2	1 3/8	10000	11
5/8	1 1/8	4000	14
5/8	1 1/4	6000	11
5/8	1 3/8	8000	11
5/8	1 1/2	10000	11
3/4	1 1/4	4000	11
3/4	1 3/8	6000	11
3/4	1 1/2	8000	11
3/4	1 5/8	10000	11
7/8	1 3/8	4000	11
7/8	1 1/2	6000	11
Inches.	Inches.		
7/8	1 5/8	8000	11
7/8	1 3/4	10000	11
1	1 1/2	4000	11
1	1 5/8	6000	11
1	1 3/4	8000	11
1	1 7/8	10000	11
1 1/8	1 5/8	4000	11
1 1/8	1 3/4	6000	11
1 1/8	1 7/8	8000	11
1 1/8	2	10000	11
1 1/4	1 3/4	4000	11
1 1/4	1 7/8	6000	11
1 1/4	2	8000	11
1 1/4	2 1/8	10000	11
1 3/8	1 7/8	4000	11
1 3/8	2	6000	11
1 3/8	2 1/8	8000	11
1 3/8	2 1/4	10000	11
1 1/2	2	4000	11
1 1/2	2 1/8	6000	11
1 1/2	2 1/4	8000	11
Inches.	Inches.		
1 1/2	2 3/8	10000	11
1 1/2	2 1/2	10000	11
1 5/8	2 1/8	4000	11
1 5/8	2 1/4	6000	11
1 5/8	2 3/8	8000	11
1 5/8	2 1/2	10000	11
1 3/4	2 1/4	3000	11
1 3/4	2 3/8	4000	11
1 3/4	2 1/2	6000	11
1 3/4	2 5/8	8000	11
1 3/4	2 3/4	10000	11
1 7/8	2 3/8	3000	11
1 7/8	2 1/2	4000	11
1 7/8	2 5/8	6000	11
1 7/8	2 3/4	8000	11
1 7/8	2 7/8	10000	11
2	2 1/2	3000	11
2	2 5/8	4000	11
2	2 3/4	6000	11
2	2 7/8	8000	11
2	3	10000	11

Table 89.—WHITWORTH'S STANDARD SCREWS AND BOLTS.

Diameter of Screw.	Number of Threads per Inch.	Diameter at the bottom of Thread.	THICKNESS OF HEAD.		Diameter of Screw.	Number of Threads per Inch.	Diameter at the bottom of Thread.	THICKNESS OF HEAD.	
			Exact Thickness, in Decimals.	Nearest Thickness.				Exact Thickness, in Decimals.	Nearest Thickness
Inches.		Inches.	Inches.	Inches.	Inches.		Inches.	Inches.	Inches.
$\frac{1}{16}$	60				$1\frac{3}{4}$	5	1·494	1·531	$1\frac{1}{2}$ and $\frac{1}{32}$
$\frac{3}{32}$	48				$1\frac{7}{8}$	$4\frac{1}{2}$	1·590	1·6406	$1\frac{5}{8}$ and $\frac{1}{32}$
$\frac{1}{8}$	40	·093	·109	$\frac{3}{32}$	2	$4\frac{1}{2}$	1·715	1·750	$1\frac{3}{4}$
$\frac{5}{32}$	32				$2\frac{1}{8}$	$4\frac{1}{2}$	1·840	1·852	$1\frac{7}{8}$
$\frac{3}{16}$	24	·134	·164	$\frac{1}{8}$ and $\frac{1}{32}$	$2\frac{1}{4}$	4	1·930	1·968	$1\frac{15}{16}$ and $\frac{1}{32}$
$\frac{7}{32}$	24				$2\frac{3}{8}$	4	2·055	2·078	$2\frac{1}{16}$ and $\frac{1}{32}$
$\frac{1}{4}$	20	·186	·219	$\frac{5}{16}$ and $\frac{1}{32}$	$2\frac{1}{2}$	4	2·180	2·187	$2\frac{3}{16}$
$\frac{5}{16}$	18	·241	·273	$\frac{1}{4}$ and $\frac{1}{32}$	$2\frac{5}{8}$	4	2·305	2·297	$2\frac{1}{4}$ and $\frac{1}{32}$
$\frac{3}{8}$	16	·295	·328	$\frac{5}{16}$	$2\frac{3}{4}$	$3\frac{1}{2}$	2·384	2·406	$2\frac{3}{8}$ and $\frac{1}{32}$
$\frac{7}{16}$	14	·346	·383	$\frac{3}{8}$ and $\frac{1}{32}$	$2\frac{7}{8}$	$3\frac{1}{2}$	2·509	2·516	$2\frac{1}{2}$ and $\frac{1}{32}$
$\frac{1}{2}$	12	·393	·437	$\frac{7}{16}$	3	$3\frac{1}{2}$	2·634	2·625	$2\frac{5}{8}$
$\frac{9}{16}$	12	·456	·492	$\frac{7}{16}$ and $\frac{1}{32}$	$3\frac{1}{4}$	$3\frac{1}{4}$	2·884	2·843	$2\frac{13}{16}$ and $\frac{1}{32}$
$\frac{5}{8}$	11	·508	·547	$\frac{1}{2}$ and $\frac{1}{32}$	$3\frac{1}{2}$	$3\frac{1}{4}$	3·106	3·062	$3\frac{1}{16}$
$\frac{11}{16}$	11	·571	·601	$\frac{5}{8}$	$3\frac{3}{4}$	3	3·356	3·281	$3\frac{1}{4}$ and $\frac{1}{32}$
$\frac{3}{4}$	10	·622	·656	$\frac{5}{8}$ and $\frac{1}{32}$	4	3	3·574	3·500	$3\frac{1}{2}$
$\frac{13}{16}$	10	·684	·711	$\frac{9}{16}$ and $\frac{1}{32}$	$4\frac{1}{4}$	$2\frac{7}{8}$	3·824	3·718	$3\frac{11}{16}$ and $\frac{1}{32}$
$\frac{7}{8}$	9	·733	·766	$\frac{3}{4}$ and $\frac{1}{32}$	$4\frac{1}{2}$	$2\frac{7}{8}$	4·055	3·937	$3\frac{15}{16}$
$\frac{15}{16}$	9	·795	·820	$\frac{3}{4}$ and $\frac{1}{32}$	$4\frac{3}{4}$	$2\frac{3}{4}$	4·305	4·156	$4\frac{1}{8}$ and $\frac{1}{32}$
1	8	·840	·875	$\frac{7}{8}$	5	$2\frac{3}{4}$	4·534	4·375	$4\frac{3}{8}$
$1\frac{1}{8}$	7	·942	·984	1	$5\frac{1}{4}$	$2\frac{5}{8}$	4·764	4·593	$4\frac{9}{16}$ and $\frac{1}{32}$
$1\frac{1}{4}$	7	1·067	1·094	$1\frac{1}{16}$ and $\frac{1}{32}$	$5\frac{1}{2}$	$2\frac{5}{8}$	5·014	4·812	$4\frac{13}{16}$
$1\frac{3}{8}$	6	1·161	1·203	$1\frac{3}{16}$ and $\frac{1}{32}$	$5\frac{3}{4}$	$2\frac{1}{2}$	5·238	5·031	$5\frac{1}{32}$
$1\frac{1}{2}$	6	1·286	1·312	$1\frac{5}{16}$	6	$2\frac{1}{2}$	5·488	5·250	$5\frac{1}{4}$
$1\frac{5}{8}$	5	1·369	1·412	$1\frac{3}{8}$ and $\frac{1}{32}$					

NOTE.—Thickness of nut is equal to the diameter of bolt.

Bolts and Screws.—The width across the flats of the bolt-head, is the same as for nuts given in Table 107, page 305. The width across the flats is approximately equal to $1\frac{1}{2}$ times the diameter of the bolt added to $\frac{3}{32}$. The angle of the *triangular thread* is 55°, the height of the triangle of thread is reduced one-third by rounding one-sixth off the top, and one-sixth off the bottom of thread. Depth of thread = the pitch multiplied by ·64. To find the diameter at the bottom of the thread, multiply the pitch by 1·28, and subtract the product from the outside diameter.

For screws with square threads, the number of threads per inch is **one-half** of the number for triangular threads, and the depth of thread is $\frac{19}{40}$ of the pitch, or equal to the space between the threads.

Table 90.—Gauges for Watch and Instrument Makers, with Screw-Threads for the Various Sizes.

Number of each size in thousandths of an Inch.	Size in decimals of an Inch.	Number of Threads per Inch.	Number of each size in thousandths of an Inch.	Size in decimals of an Inch.	Number of Threads per Inch.
10	·010	400	34	·034	150
11	·011	400	36	·036	150
12	·012	350	38	·038	120
13	·013	350	40	·040	120
14	·014	300	45	·045	120
15	·015	300	50	·050	100
16	·016	300	55	·055	100
17	·017	250	60	·060	100
18	·018	250	65	·065	80
19	·019	250	70	·070	80
20	·020	210	75	·075	80
22	·022	210	80	·080	60
24	·024	210	85	·085	60
26	·026	180	90	·090	60
28	·028	180	95	·095	60
30	·030	180	100	·100	50
32	·032	150			

Conducting Power of Metals for Electricity at 32° Fahr.:—

Silver	100	Tin	14
Copper	92	Iron	13
Gold	65	Lead	8·3
Zinc	29	Platinum	8
Bronze	22	German silver	5·9
Brass	18	Bismuth	1·9

The conductivity diminishes as the temperature increases above 32° F.

SECTION VI

STRENGTH AND WEIGHT OF MATERIALS: WORKSHOP DATA, &c.

SECTION VI.

STRENGTH AND WEIGHT OF MATERIALS; WORKSHOP DATA, &c.

Strength of Wrought-Iron.—The tensile strength of wrought-iron is about four times as great as that of cast-iron; good wrought-iron should be capable of standing the following tensile strains before breaking, in tons per square inch of section.

	Tons.	
Lowmoor or "Best Yorkshire" bar iron	26	The safe working tensile strength is ¼ of these amounts for general purposes.
Ordinary good merchant bar iron	25	
Lowmoor or "Best Yorkshire iron" plates along the fibre	24	
Lowmoor or "Best Yorkshire iron" plates across the fibre	22	
Ordinary good angle iron	22	
Ordinary good boiler-plates along the fibre . . .	21	
Ordinary good boiler-plates across the fibre . . .	18	
Ordinary good ship-plates along the fibre	20	
Ordinary good ship-plates across the fibre . . .	17	

The strength of wrought-iron to resist a crushing or compressive strain is about half that of its tensile resistance, or say 12 tons, and its working strength in compression free from flexure is one-quarter that amount, or 3 tons per square inch of section.

Testing Wrought-Iron.—Good wrought-iron has a fine close-grained fracture of silvery grey colour; inferior quality has a coarse granular fracture similar to that of cast-iron. The elongation under tensile strain is a test of the toughness of wrought iron; the ultimate elongation after fracture of Lowmoor iron plates is about 13 per cent., and of ordinary good iron boiler-plates 7 per cent., and of ordinary good ship-plates 5 per cent., of their original length when torn along the fibre. Lowmoor or best Yorkshire iron plates under ½ inch thick, should bend double when cold without fracture; and from ½ inch to 1 inch thick, should bend double when hot, both lengthways and across the fibre without fracture. The tests for ordinary wrought-iron boiler and ship-plates are the same as those used by the Admiralty, which are given below.

Admiralty Tests for Wrought-Iron Boiler-Plates.—All boiler-plates (with the exception of Lowmoor and Bowling iron, which are not tested) must be capable of standing the following test:—

Tensile strain per square inch lengthways, 21 tons: crossways, 18 tons.

Forge-Test, Hot.—Plates to admit of being bent hot, without fracture, to the following angles.

Lengthways of the grain, 125°; across, 100°.

Forge-Test, Cold.—Plates to admit of being bent cold, without fracture, to the following angles.

Thickness of Plate, in Inches	$\frac{3}{16}$ and under	$\frac{1}{4}$ and $\frac{5}{16}$	$\frac{3}{8}$ and $\frac{7}{16}$	$\frac{1}{2}$. $\frac{9}{16}$, $\frac{5}{8}$	$\frac{11}{16}$ and $\frac{3}{4}$	$\frac{13}{16}$ and $\frac{7}{8}$	$\frac{15}{16}$ and 1 Inch.
Lengthways of the Grain . .	90°	70°	50°	35°	25°	20°	15° angle.
Across the Grain . . .	40°	30°	20°	15°	10°	5°	5° angle.

Admiralty Test for Ship-Plates.—Plate iron, first-class BB.; tensile strain per square inch, lengthways, 22 tons; crossways, 18 tons.

Forge-Test, Hot.—All plates of the first-class, 1 inch thick and under should be of such ductility as to admit of bending hot, without fracture, to the following angles. Lengthways of the grain, 125°; across, 90°.

Forge-Test, Cold.—All plates of the first-class, should admit of bending cold, without fracture, to the angles given in the above table.

Plate-Iron Second-class B., tensile strain per square inch lengthways, 20 tons; crossways, 17 tons.

Forge-Test, Hot.—All plates of the second class, 1 inch thick and under, should be of such ductility as to admit of bending hot, without fracture, to the following angles. Lengthways of the grain, 90°; across, 60°.

Forge-Test, Cold.—All plates of the second class should admit of bending cold, without fracture, to the following angles.

Thickness of Plate, in Inches	$\frac{3}{16}$ and under	$\frac{1}{4}$ and $\frac{5}{16}$	$\frac{3}{8}$ and $\frac{7}{16}$	$\frac{1}{2}$, $\frac{9}{16}$, $\frac{5}{8}$	$\frac{11}{16}$ and $\frac{3}{4}$	$\frac{13}{16}$ and $\frac{7}{8}$	$\frac{15}{16}$ and 1 Inch.
Lengthways of the Grain . .	75°	55°	45°	30°	20°	15°	10° angle.
Across the Grain . . .	30°	20°	15°	10°	5°	—	— angle.

Steel Boiler-Plates are generally made of the best quality of mild-steel, their tensile strength is about one-third greater than that of Lowmoor iron, and they should stand the following test before breaking. Tensile strain per square inch both lengthways and crossways, 28 to 30 tons. All steel plates 1 inch thick and under, to admit of being bent double when hot, without fracture, and to admit of bending cold, without fracture, to the angles given in the table below. The safe working tensile strength, is one-fourth the breaking strain, or from 7 to $7\frac{1}{2}$ tons per square inch of section.

Thickness of Steel Plate, in Inches	$\frac{1}{4}$ and under	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$ and $\frac{9}{16}$	$\frac{5}{8}$ and $\frac{11}{16}$	$\frac{3}{4}$ and $\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$ and 1 Inch.
Lengthways of Grain, Angle .	120°	120°	110°	90°	80°	70°	60°	50°	45° angle.
Across the Grain, Angle . .	100°	90°	80°	70°	60°	50°	40°	30°	25° angle.

Steel Plates are generally riveted, with the best quality of steel rivets, slightly smaller in diameter, and closer in pitch, than for wrought-iron plates. Steel rivets should be made from bars of a very mild quality, otherwise the heads are liable to fly off from jars. Plates both hot and cold, are tested on a true surface-plate, the radius of the corner over which they are bent being ½ inch, the distance from the edge of the plate to the part bent, is from 3 to 6 inches. When plates are tested hot, they are heated to an orange colour; the plates are bent down to the required angle by hammering.

Tests for Rivets.—They should be made from bars of the toughest quality, and admit of being bent double, without fracture, when cold. The heads should admit of being hammered down to ⅛ inch in thickness without fracturing the edges, when hot.

Test for Wrought-Iron Bridge-Plates.—A piece of plate is cut 2 inches wide and ½ inch thick, of sufficient length to have 7 inches under tension, the plates being rejected if the extension of the test-piece is greater than ⅛ inch under a test of 18 tons, ¼ inch under 21 tons, ½ inch under 23 tons, ¾ inch under 24 tons. All bar iron to stand a tensile strain of 25 tons, per square inch of section, before fracture.

Diminution of Tenacity of Iron Boiler-plates at high temperatures, the mean maximum tenacity being at 550° F.=65,000 lbs. per square inch. From the experiments of the Franklin Institute.

Temperature.	Diminution of Tenacity.	Temperature.	Diminution of Tenacity.
520°	·0738	824°	·2010
570°	·0870	932°	·3324
596°	·0900	947°	·3593
600°	·0964	1030°	·4478
630°	·1047	1111°	·5514
662°	·1155	1155°	·6000
722°	·1436	1159°	·6011
732°	·1491	1187°	·6352
754°	·1535	1237°	·6622
766°	·1589	1245°	·6715
770°	·1628	1317°	·7000

Effects of Re-heating and Rolling Iron, from the results of various experiments.

Puddled Bar. Tenacity in lbs. per square inch	43.904
The same iron, 5 times piled, re-heated, and rolled. Tenacity in lbs. per square inch	61,824
The same iron, 11 times piled, re-heated, and rolled. Tenacity in lbs. per square inch	43,904

Steel Plates and Bars used in place of wrought iron, to be of equal strength, may in a general way be made 20 per cent. thinner than wrought iron plates and bars.

ROPES AND CHAINS.

The Breaking Strain of hemp-ropes, is 1 ton, for each lb. weight per fathom.

The breaking strain of iron-wire ropes is 2 tons, for each lb. weight per fathom.

The breaking strain of steel-wire ropes is 3 tons, for each lb. weight per fathom.

Table 91.—Size, Weight and Strength of Steel- and Iron-Wire Ropes and Hemp-Ropes.

Steel-Wire Ropes.		Iron-Wire Ropes.		Hemp-Ropes of Equivalent Strength.			
Circumference in Inches.	Weight per Fathom in lbs.	Circumference in Inches.	Weight per Fathom in lbs.	Circumference in Inches.	Weight per Fathom in lbs.	Safe Working Load in Cwts.	Breaking Strain in Tons.
3½	11	4⅝	18	12	32	108	34
3⅜	9½	4¼	16	11	30	96	29
3⅛	8¼	4	14	10	28	84	25
3	7½	3¾	13	9½	25	78	23
2⅞	7	3⅝	11¾	9	22	70	21
2¾	6	3½	11	8½	20	66	19
2⅝	5¾	3⅜	9½	8	16	57	17
2½	4¾	3⅛	8¼	7½	14	50	15
2⅜	4½	3	7½	7	12	45	14
2¼	4	2⅞	7	6½	10	42	13
2⅛	3¾	2¾	6	6	9	36	11
2	3¼	2⅝	5¾	5½	8	34	10
1⅞	3	2½	4¾	5	7	28	9
...	...	2⅜	4½	4¾	6½	27	8
1¾	2½	2¼	4	4½	6	24	7
...	...	2⅛	3¾	4	5	22	6½
...	...	2	3¼	3¾	4½	20	6
1½	1¾	1⅞	3	3½	4	18	5
1⅜	1½	1¾	2½	3	3½	15	4
1¼	1¼	1½	1¾	2¾	3	10	3
1⅛	1	1⅜	1½	2½	2½	8	2½
⅞	¾	1¼	1¼	2¼	2	6	2
¾	½	1⅛	1	2	1½	4	1½
...	...	⅞	¾	1¾	1	3	1
...	...	¾	½	1½	¾	1½	¾

Hemp-Ropes.—Tarred ropes are weaker than white ropes, hot-spun tarred ropes are stronger than cold-spun, but are not so pliable.

Wet-Ropes.—When a rope is wet, it expands in diameter, and contracts in length, owing to the fibres being drawn in by this increase of diameter.

Hemp-Fibres are about a yard in length, the tensile strength of hemp-fibres is 6,400 lbs. per square inch of sectional area.

Table 92.—SIZE, WEIGHT, AND STRENGTH OF STEEL, IRON AND HEMP FLAT ROPES.

STEEL-WIRE ROPES.		IRON-WIRE ROPES.		HEMP-ROPES OF EQUIVALENT STRENGTH.			
Size in Inches.	Weight per Fathom in lbs.	Size in Inches.	Weight per Fathom in lbs.	Size in Inches.	Weight per Fathom in lbs	Safe Working Load in cwts	Breaking Strain in Tons.
3 1/4 × 5/8	18	4 1/2 × 7/8	30	8 1/2 × 2 1/4	45	120	45
3 × 5/8	16	4 1/4 × 13/16	27	7 1/2 × 2 1/8	40	108	40
2 7/8 × 9/16	14	4 × 3/4	24	7 × 1 7/8	36	96	36
...	...	3 3/4 × 3/4	22	6 1/2 × 1 5/8	32	88	32
2 3/4 × 1/2	12 1/2	3 1/2 × 11/16	20	6 × 1 1/2	28	80	28
...	...	3 1/4 × 5/8	18	5 3/4 × 1 1/2	27	72	27
2 × 5/8	10	3 × 5/8	16	5 1/2 × 1 3/8	26	64	26
1 1/8 × 1/2	8	2 7/8 × 9/16	14	5 1/4 × 1 1/4	24	56	24
...	...	2 3/4 × 1/2	12	5 × 1 1/4	22	48	22
...	...	2 × 5/8	10	4 × 1 1/8	20	40	20
...	...	1 7/8 × 1/2	8	3 × 1	16	32	16

Table 93.—WEIGHT, WORKING LOAD, PROOF STRAIN AND BREAKING STRAIN OF CHAINS AND CABLES.

SHORT-LINK OR CRANE-CHAIN.					STUD-LINK CHAIN-CABLE.				
Diameter of Iron in the Chain in Inches.	Weight per Fathom in lbs.	Safe Working Load in Tons.	Proof Strain in Tons.	Breaking Strain in Tons.	Diameter of Iron in the Chain in Inches.	Weight per Fathom in lbs.	Safe Working Load in Tons.	Proof Strain in Tons.	Breaking Strain in Tons.
5/16	5 1/2	9/16	1 1/8	2 1/4	1/2	13 1/2	2 1/4	4 1/2	7
3/8	8	13/16	1 5/8	3 1/4	5/8	21	3 1/2	7	11
7/16	10 1/2	1 1/8	2 1/4	4 1/2	3/4	30	5	10 1/8	16
1/2	13 3/4	1 1/2	3	6	7/8	42	6 3/4	13 3/4	22
9/16	17	1 7/8	3 3/4	7 1/2	1	54	9	18	28
5/8	22	2 5/16	4 5/8	9 1/4	1 1/8	69	11 3/8	22 3/4	36
11/16	26	2 13/16	5 5/8	11 1/4	1 1/4	84	14	28 1/8	44
3/4	30	3 3/8	6 3/4	13 1/2	1 3/8	102	17	34	54
13/16	36	3 15/16	7 7/8	15 3/4	1 1/2	121	20 1/4	40 1/2	64
7/8	42	4 1/16	9 1/8	18 1/4	1 5/8	142	23 3/4	47 1/2	74
15/16	49	5 1/4	10 1/2	21	1 3/4	165	27 9/16	55 1/8	86
1	55	6	12	24	1 7/8	189	31 1/2	63 1/4	99
1 1/16	60	7	14	28	2	215	36	72	113
1 1/8	68	7 5/8	15 1/4	30 1/2	2 1/8	243	40 1/2	81 1/4	128
1 3/16	76	8 1/4	16 3/4	33 1/2	2 1/4	277	45 1/2	91 1/8	143
1 1/4	84	9 3/8	18 3/4	37 1/2	2 3/8	304	50 3/4	101 1/2	159
1 3/8	102	11 5/16	22 5/8	45 1/4	2 1/2	336	56 1/4	112 1/2	176
1 1/2	120	13 1/2	27	54	2 3/4	407	68	136 1/8	213

Standard Proportions of the links of chains in terms of the diameter of the iron from which they are made:—

Stud-link = 6 diameters extreme length, and 3·6 diameters extreme width.

Close-link = 5 diameters extreme length, and 3·5 diameters extreme width.

Open-link = 6 diameters extreme length, and 3·5 diameters extreme width.

Middle-link = 5·5 diameters extreme length, and 3·5 diameters extreme width.

End-link of each, 15 fathom length of chain, 6·5 diameters extreme length, and 4·1 diameters extreme width.

Strength of Chains and Ropes.—To find the breaking strain in tons of short-link chains, square the number of eighths of an inch in the diameter of the iron from which the link is made, and multiply by ·375.

To find the breaking strain in tons of stud-link chains, square the number of eighths of an inch in the diameter of the iron from which the link is made, and multiply by ·44.

To find the breaking strain in tons of ropes of hemp, and of iron and steel wire:—

For hemp ropes, square the circumference in inches and multiply by ·25.

For iron-wire ropes, square the circumference in inches and multiply by 1·5.

For steel-wire ropes, square the circumference in inches and multiply by 2·5.

The working or safe load for ropes is from one-sixth to one-seventh of the breaking strain, for round hemp ropes, and for round iron-wire ropes: one-eighth for flat hemp and for flat iron-wire ropes: one-sixth for round steel wire: and one-seventh for flat steel-wire ropes.

GIRDERS.

Girders and Beams.—To find the breaking weight in tons, of solid beams of wood or iron, square or rectangular, with both ends supported, and loaded in the middle:—*Rule:* Multiply the square of the depth in inches by the breadth in inches, and divide the product by the length in feet between the supports; the result will be the breaking weight in tons of a cast-iron beam. For wrought-iron, multiply the said result by 1·5; for oak, multiply by ·25; and for pine or fir, multiply by ·2.

Wood Girders with wrought-iron flitch-plates.—To find the breaking weights in cwts., when loaded in the middle, with both ends supported.—*Rule* for fir: Multiply five times the square of the depth in inches, by the breadth in inches, including the iron flitch plate, and divide the product by the length in feet. For oak, use 6 as a multiplier instead of 5. The thickness of the iron flitch-plate should be one-tenth that of the wood, for which thickness the above rule applies.

Solid-rolled wrought-iron joists and girders, Fig. 148. To find the breaking weight in tons when loaded in the middle, with both ends supported. *Rule :* Add one-fourth the area of the web in inches, calculated on the full depth of joist, to the area of the bottom flange in inches; multiply that sum by the depth in inches; multiply the product by 6·6, and divide the result by the length in feet between the supports.

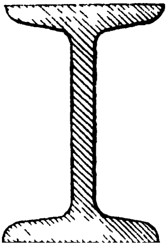


Fig. 148.—Rolled-Joist.

Box-girders are about 10 per cent. less in strength than solid rolled joists or girders, of equal depth and weight.

Single-web girders are about 20 per cent. less in strength than solid rolled joists or girders, of equal depth and weight.

T girders are about 40 per cent. less in strength than solid rolled joists or girders, of equal depth and weight.

Riveted joists are about 50 per cent. less in strength than solid rolled joists or girders, of equal depth and weight.

The Deflection of solid-rolled joists is about 50 per cent. less than that of riveted joists, of equal depth and weight.

A girder fixed at one end only, and loaded at the other end, will support only one-fourth the load that a girder of the same length will bear, when supported at both ends and loaded in the middle.

A girder will support only one-half the load at the middle, that it will if distributed over its length.

Factor of safety for girders. The safe dead load for wrought-iron girders is generally $\frac{1}{4}$ the breaking weight, and for cast-iron girders $\frac{1}{6}$ the breaking weight; for moving loads the factor of safety should be double that used for dead loads.

Solid Round Beams and girders. To find the breaking weight, in tons, of a solid round beam, with both ends supported, and loaded in the middle:—Cube the diameter in inches, and divide by the length in feet between the supports; the result will be the breaking weight in tons of a wrought iron round beam; for cast-iron multiply the said result by ·66; for oak multiply by ·17; for fir or pine multiply by ·13.

Table 94.—PROPORTIONS AND SAFE DEAD DISTRIBUTED LOAD, FOR ROLLED WROUGHT-IRON GIRDERS AND JOISTS, Fig. 148.

SECTIONAL DIMENSIONS.			Weight per Foot.	CLEAR SPAN IN FEET, OR DISTANCE BETWEEN THE SUPPORTS.												
Depth of Girder and Breadth of Flanges.	Thickness of Web.	Thickness of Flanges.		Feet. 6	Feet. 8	Feet. 10	Feet. 12	Feet. 14	Feet. 16	Feet. 18	Feet. 20	Feet. 22	Feet. 24	Feet. 26	Feet. 28	Feet. 30
Inches.	Inches.	Inches.	lbs.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
16 × 6 × 6	$\frac{9}{16}$	$\frac{13}{16}$	63	58	46	37	30	26	23	20	18	17	14	13	12	10
14 × 6 × 6	$\frac{9}{16}$	$\frac{13}{16}$	60	53	40	31	26	22	19	18	15	13	11	10	9	8
12 × 6 × 6	$\frac{9}{16}$	$\frac{15}{16}$	56	47	37	28	23	20	17	15	13	11	10	9	8	7
12 × 5 × 5	$\frac{7}{16}$	$\frac{13}{16}$	42	32	23	19	15	13	11	10	9	8	7	6	5	4
10 × 5 × 5	$\frac{7}{16}$	$\frac{13}{16}$	36	27	21	15	13	11	10	9	8	7	6	5	4	3
$9\frac{1}{2} \times 4\frac{1}{2} \times 4\frac{1}{2}$	$\frac{3}{8}$	$\frac{11}{16}$	30	22	16	11	10	8	7	6	5	4	3			
$9\frac{1}{4} \times 3\frac{3}{4} \times 3\frac{3}{4}$	$\frac{7}{16}$	$\frac{1}{2}$	24	13	10	8	6	5	4	$3\frac{1}{2}$	3	$2\frac{1}{2}$				
8 × 5 × 5	$\frac{3}{8}$	$\frac{9}{16}$	29	14	10	8	7	6	5	4	$3\frac{1}{2}$	3				
8 × 4 × 4	$\frac{3}{8}$	$\frac{1}{2}$	22	12	9	7	6	5	4	$3\frac{1}{2}$	3	$2\frac{1}{2}$				
$8 \times 2\frac{5}{8} \times 2\frac{5}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	15	7	$5\frac{1}{2}$	$4\frac{1}{2}$	$3\frac{1}{2}$	3	$2\frac{1}{2}$	2	$1\frac{3}{4}$	$1\frac{1}{2}$				
$7 \times 3\frac{5}{8} \times 3\frac{5}{8}$	$\frac{5}{16}$	$\frac{1}{2}$	20	6	5	$3\frac{1}{2}$	3	$2\frac{1}{2}$	2	$1\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$				
$7 \times 2\frac{1}{4} \times 2\frac{1}{4}$	$\frac{5}{16}$	$\frac{7}{16}$	14	$4\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{1}{2}$	2	$1\frac{3}{4}$	$1\frac{1}{2}$	1						
6 × 5 × 5	$\frac{7}{16}$	$\frac{9}{16}$	28	$8\frac{1}{2}$	6	5	4	3	$2\frac{1}{2}$	2	$1\frac{1}{2}$					
6 × 3 × 3	$\frac{5}{16}$	$\frac{7}{16}$	16	$5\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{1}{2}$	2	$1\frac{1}{2}$	$1\frac{1}{4}$	1					
$6\frac{1}{4} \times 2 \times 2$	$\frac{5}{16}$	$\frac{7}{16}$	11	$3\frac{1}{2}$	$2\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	1							
$5 \times 4\frac{1}{2} \times 4\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{2}$	23	$5\frac{1}{2}$	$4\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{4}$	2	$1\frac{1}{2}$	$1\frac{1}{4}$	1				
5 × 3 × 3	$\frac{5}{16}$	$\frac{7}{16}$	13	$4\frac{1}{2}$	3	$2\frac{1}{4}$	2	$1\frac{1}{2}$	$1\frac{1}{4}$	1						
$4\frac{3}{4} \times 2 \times 2$	$\frac{1}{4}$	$\frac{5}{16}$	8	$1\frac{1}{2}$	$1\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{1}{2}$								
4 × 3 × 3	$\frac{1}{4}$	$\frac{3}{8}$	12	2	$1\frac{1}{2}$	$1\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{1}{2}$							
4 × 2 × 2	$\frac{1}{4}$	$\frac{5}{16}$	7	$1\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{1}{2}$									
3 × 3 × 3	$\frac{1}{4}$	$\frac{5}{16}$	10	$1\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{1}{2}$									
$3 \times 1\frac{1}{2} \times 1\frac{1}{2}$	$\frac{3}{16}$	$\frac{7}{32}$	5	$\frac{3}{4}$	$\frac{1}{2}$											

Hollow Round Beams. To find the breaking weight in tons of a hollow round beam, subtract the cube of the inside diameter in inches from the cube of the outside diameter in inches, and divide by the length in feet between the supports, the result will be the breaking weight in tons of a hollow round wrought-iron beam; for cast-iron multiply the said result by ·66; for oak multiply by ·17; for fir or pine multiply by ·13.

Angle-Iron Beams.—The strength of equal-legged angle or Tee iron, acting as a beam, is 50 per cent. greater than that of a bar of the same height and thickness; in sections of unequal legs, the height only is to be considered.

Cast-Iron Girders, Fig. 149.—The depth of girder should be from $\frac{1}{12}$ to $\frac{1}{15}$ of the span; width of bottom flange $\frac{2}{3}$ to $\frac{3}{4}$ of the depth of girder at the centre; width of top flange one third to one-half of the bottom flange; maximum span 25 feet; for greater spans wrought-iron is safer. In order to obtain uniformity in cooling and sound castings, there should not be any sudden variation of metal, and the web should be proportioned and tapered, so as to meet each flange with a thickness corresponding to that of the flange. When the depth of girder is limited, the bottom flange is made wider in proportion. When strengthening ribs are cast on girders, they should be curved, as they are less liable to crack, than when made straight.

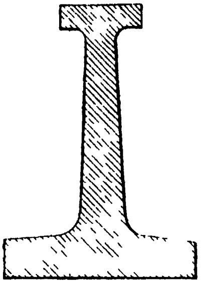


Fig. 149.—Cast-Iron Girder.

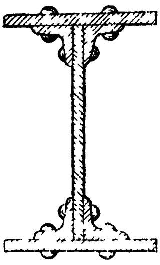


Fig. 150.—Riveted Girder.

In the strongest form of a cast-iron girder, the sectional area of the bottom flange, is six times as great as the area of the top flange, and these proportions should be followed, as closely as the proper distribution of the metal will allow, as regards freedom from undue straining, in the cooling of the casting.

The Compressive Strength of Cast-Iron of average quality is about 42 tons per square inch of section, but the tensile strength is only about 6 tons per square inch; therefore the bottom flange of cast-iron girders requires to be many times greater than the top flange. The compressive strength of ordinary wrought-iron plates, is about 12 tons per square inch of section, and the tensile strength about 20 tons per square inch; therefore, in wrought-iron girders, the top flange requires to be the greatest.

To find the breaking weight, in tons, of a cast-iron girder when loaded in the middle, and with both ends supported.—*Rule:* Multiply twice the depth in inches, by the sectional area of the bottom flange in inches, and divide the result by the length in feet between the supports.

To find the breaking weight of a uniformly-distributed load, multiply the result found by this rule by 2.

Table 95.—PROPORTIONS OF CAST-IRON GIRDERS, Fig. 50.

Safe dead distributed Load in Tons.	Clear Span in Feet.	Depth of Girder in Inches.	BOTTOM FLANGE.			TOP FLANGE.			WEB.	
			Breadth in Inches.	Thickness at the Centre in Inches.	Thickness at the Edge in Inches.	Breadth in Inches.	Thickness at the Centre in Inches.	Thickness at the Edge in Inches.	Thickness at the Bottom in Inches.	Thickness at the Top in Inches.
4	10	9	5	1¼	⅞	1½	⅝	½	⅞	¾
6	10	9	6	1⅜	1	1⅝	⅞	¾	1	⅞
12	14	12	8	2¼	1¾	2⅞	1	⅞	1⅛	1
18	15	12	12	2⅜	1¾	4⅛	1⅛	1	1⅜	1⅛
25	20	12	18	2⅞	2¼	6	1⅝	1¼	1¾	1½
30	20	12	20	3	2½	7	1¾	1⅜	2	1⅝
9	12	15	7	1⅜	1	1⅞	⅞	¾	1	⅞
18	16	15	10	2⅜	1¾	3⅜	1⅛	1	1⅜	1⅛
25	20	15	17	2⅜	1¾	5⅝	1¼	1⅛	1⅝	1⅜
30	20	15	18	2⅞	2⅜	6⅝	1½	1¼	1¾	1½
16	18	18	12	1¾	1⅛	3⅛	1	⅞	1⅛	1
25	20	18	16	2⅛	1½	4⅝	1⅛	1	1½	1¼
40	18	18	16	3⅜	2½	5¾	1¾	1¼	2	1¼
15	20	24	13	1⅜	1⅛	2⅞	1⅛	⅞	1	⅞
25	20	24	15	1¾	1⅜	4½	1¼	1⅛	1⅜	1
40	20	24	16	2⅝	1⅞	5½	1⅜	1⅛	1⅞	1¼
60	20	24	17	4½	3½	6	2⅜	1¾	2⅞	1¾
85	25	24	25	4⅝	3⅝	8	2½	1⅞	3	1⅞
40	20	30	15	2⅜	1⅝	5	1⅜	1⅛	1⅝	1⅛
60	25	30	18	3⅝	2⅞	5¼	2¼	1⅝	2	1⅜
90	25	30	25	4½	3½	8	2⅜	1¾	2⅞	1¾
130	25	30	26	5⅛	4	9	2⅞	2	3⅜	2⅛
70	25	36	19	3¾	2⅝	6	2¼	1¾	2⅛	1⅝
100	25	36	25	4¼	3⅛	8	2¼	1¾	2¼	1¾
130	25	36	26	4¾	3¾	9	2½	1⅞	3¼	2

To find the area of the bottom flange in inches.—*Rule:* Multiply the length in feet by the permanent distributed load in tons, and divide the product by the depth in inches of the girder.

To find the permanent distributed load.—Rule: Multiply the depth in inches by the sectional area of bottom flange in inches, and divide by the length in feet of the girder.

To find the weight in lbs. of a brick wall carried by a girder, multiply the height in feet by the length in feet of brickwork, and then multiply by the number of bricks the wall is thick (that is by 2, if the wall is 2 bricks thick, and so on) and multiply by 75, which result divided by 2240 will give the weight of the wall in tons, or load distributed over the whole length of girder.

Riveted Wrought-Iron Girders, Fig. 150. To find the breaking weight in tons, of a girder with a single plate or web united by angle-irons to top and bottom flanges, when loaded in the middle and with both ends supported.—*Rule :* Multiply 5·7 times the depth of girder in inches by the area of the bottom flange in inches, and divide by the length in feet between the supports (the area of the bottom flange to include the angle-iron). To calculate the area of the bottom flange, multiply the width of flange-plate in inches, by its thickness in inches, to which result add the area of the 2 angle irons, which may be found by the following rule.

To find the sectional area in square inches of an angle-iron, add together the width of its two sides, from which sum subtract the thickness of metal, all in inches, and multiply the remainder by the thickness of metal in inches; thus a 3 inch angle iron $\frac{1}{2}$ inch thick has a sectional area of $(3 + 3 - \cdot 5) \times \cdot 5 = 2\cdot 75$ square inches, and as there are 2 angle irons, double the area thus found must be added to the area of the flange-plate.

To find the sectional area in square inches of the bottom flange of wrought-iron riveted girders. *Rule :* Multiply the breaking weight in tons, by the span or length between the supports in feet, and divide the product by 5·7 times the depth of girder in inches.

The depth of wrought-iron riveted girders should be $\frac{1}{12}$ of the span.

Box-Girders are 10 per cent. stronger than single-plate girders, of equal depth and weight.

Pitch of Rivets for riveted girders. For the compression member, 3 inch pitch for small, and 4 inch pitch for large girders; for the tension member, 6 inch pitch for both large and small girders.

Steel Joists and Girders.—Rolled steel simple joists are of uniform single-web section, with flanges at the top and bottom. The tensile strength of mild steel used for joists and girders is from 26 to 32 tons per square inch, with an elongation of 20 per cent. in 8 inches.

The Deflection of a Steel-Girder in inches when fully loaded, may be found approximately by this rule, by Kent :-

$$\frac{(\text{Span in Feet})^2.}{\text{Effective depth of the girder in feet} \times 700.}$$

The effective depth of a girder is the distance between the centre of area of the flanges.

For a wrought-iron girder use a constant of 900 instead of 700.

The Depth of a Girder governs its stability. Steel joists and girders are not so rigid as iron joists and girders, and they should, therefore, be deeper. The full depth of a steel joist or girder should not be less than $\frac{1}{20}$, but rather from $\frac{1}{10}$ to $\frac{1}{15}$, of the clear span of the girder.

The loads and particulars in the five following Tables are as estimated by Measures Bros., Limited, London.

Table 96.—ESTIMATED SAFE PERMANENT DISTRIBUTED LOADS IN TONS ON ROLLED STEEL SIMPLE JOISTS, WITH ENDS FIRMLY FIXED.

Sectional Dimensions.		Weight of the Joist per Foot, in Length.	LENGTH OF THE CLEAR SPAN OF THE JOIST, IN FEET.						
Depth.	Breadth.		12 Feet.	14 Feet.	16 Feet	18 Feet.	20 Feet.	22 Feet.	24 Feet.
Inches.	Inches.	Lbs.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
$19\frac{3}{4}$	× $7\frac{1}{4}$	95	98·4	84·3	73·8	65·6	59·0	53·6	49·2
$17\frac{3}{4}$	× $6\frac{3}{4}$	78	73·3	62·8	55·0	48·8	44·0	40·0	36·6
16	× 6	62	54·0	46·3	40·5	36·0	32·4	29·4	27·0
$15\frac{3}{4}$	× $6\frac{3}{32}$	62	52·4	45·0	39·2	35·0	31·2	28·2	25·8
15	× 6	58	45·4	38·9	34·0	30·3	27·2	24·7	22·7
14	× 6	52	38·7	33·2	29·0	25·8	23·2	21·1	19·3
$13\frac{13}{16}$	× $5\frac{1}{2}$	48	36·7	31·5	27·5	24·5	22·0	20·0	
12	× $6\frac{1}{2}$	64	37·0	31·7	27·8	24·7	22·2		
12	× 6	45	27·7	23·7	20·7	18·5	16·6		
12	× 5	37	22·9	19·6	17·3	15·3	13·7		
10	× 6	42	21·8	18·7	16·4				
10	× 5	30	15·5	13·2	11·6				
$9\frac{1}{2}$	× $4\frac{1}{2}$	24	11·7	10·0	8·7				
8	× 6	30	12·5	10·7					

The loads in this Table are approximately equal to one-third of the Breaking Loads.

For loads on Joists of shorter or longer span than given in this Table, multiply the load for a Joist 12 feet long by 12, and divide the product by the length in feet of the required span.

The total Safe Distributed Load on a Rolled-Steel Simple Joist in terms of its weight, may be estimated approximately by the following formula, which includes the weight of the joist:—

Total safe distributed load on a rolled-steel simple joist in tons =

$$\left[(W - H \times B \times \cdot 3) \times \frac{H}{L}\right] \times A$$

in which W = the weight in lbs. of one foot in length of the joist; B = the breadth of the flange in inches; H = the full depth of the joist in inches; L = the clear span in feet; and A = 1·20 for a factor of safety of 3; A = ·72 for a factor of safety of 5; A = ·60 for a factor of safety of 6; and A = ·36 for a factor of safety of 10.

Take, for instance, a rolled-steel joist, 12 inches deep, 6 inches broad, and 10 feet long between its supports, weighing 45 lbs. per foot in length. Then, for a factor of safety of 5, the total safe distributed load on the joist is = (45 lbs.—12 × 6 inches × ·3) × (12 inches ÷ 10 feet) × ·72 = 28·08 tons, including the weight of the joist.

The Breaking Loads of Rolled-Steel Simple Joists may be estimated approximately by the above formula, if the value of A be taken at 3·6.

A Dead Load, or gradually applied steady constant stress, should not generally be greater than one-fourth of the breaking load. A live load, or suddenly applied stress producing vibration, is twice as destructive as a dead load, and it is therefore equivalent to double the proper dead load.

Compound Girders are formed of two or more simple joists connected by ferrules and bolts, or plates and rivets.

The Clear Span of a Girder is the distance between its supports.

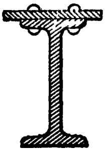


FIG. 150 A.

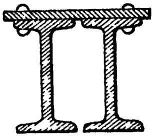


FIG. 150 B.

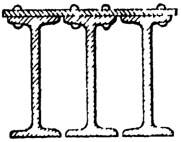


FIG. 150 C.

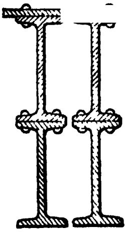


FIG. 150 D.

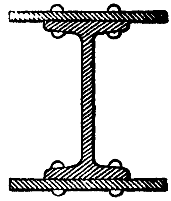


FIG. 150 E.

Figs. 150 A to 150 E represent sections of steel-girders.

Table 96A.—ESTIMATED SAFE PERMANENT DISTRIBUTED LOADS IN TONS ON GIRDERS FORMED OF STEEL-JOISTS, OR COMPOUND STEEL-GIRDERS.

Section like Fig.	Depth of Girder and Breadth of Top Flange, in Inches	Weight of the Girder per Foot, in Length	LENGTH OF THE CLEAR SPAN OF THE GIRDER, IN FEET.					
			12 Feet.	16 Feet	18 Feet.	20 Feet.	24 Feet.	30 Feet.
	Depth. Breadth.	Lbs	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
150 A	10½ × 6	40	17½	13¼				
150 A	12½ × 8	53	30¾	23	20½			
150 A	13 × 9	71	37	28	24¾	22¼		
150 B	9¾ × 9	59	26	19½				
150 B	8½ × 12	76	34	25½				
150 B	10½ × 14	110	58	43½				
150 B	12½ × 12	96	55¾	42	37¼	33½		
150 B	14¼ × 14	122	80½	60¼	53½	48¼	40	
150 C	10½ × 16	121	61½	46¼				
150 C	12½ × 16	144	82½	61½	55	49½		
150 D	20½ × 12	146	85¼	64	57	51¼	42½	34
150 E	13 × 9	71	37	28	24¾	22¼		
150 E	13 × 12	89	52	39	34¾	31¼		
150 E	14¾ × 9	83	48¼	36	32¼	29	24	
150 E	16¾ × 9	97	67	50	44¾	40¼	33	
150 E	18¾ × 12	124	98¼	73½	65½	58¾	49	39
150 E	20¾ × 12	140	123	92	82	73¾	61½	49
150 F	11 × 14	136	70½	53	47			
150 F	13½ × 12	154	95	72	63¼	57		
150 F	14¾ × 14	148	99	74¼	66	59½	49½	
150 F	16¾ × 14	176	132½	99¼	88¼	79½	66¼	53
150 G	14 × 12	158	112	84	74¾	67¼	56	
150 H	15¾ × 14	198	136¾	102½	91	82	68¼	
150 H	17¾ × 14	226	178	133½	118¾	106¾	89	71¼
150 I	22½ × 12	228	198¼	148½	132¼	119	99	79¼

The loads in the above table are approximately equal to one-third of the breaking loads.

Figs. 150 F to 150 Q represent sections of girders. Figs 150 R and 150 S represent flitch-beams

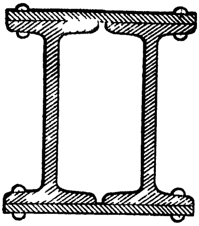


Fig. 150 F

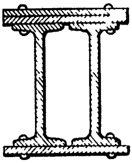


Fig. 150 G

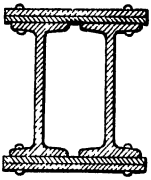


Fig. 150 H

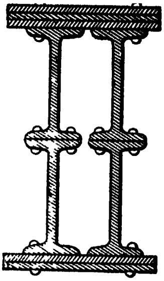


Fig. 150 I

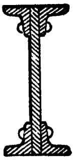


Fig. 150 J

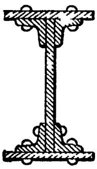


Fig. 150 K

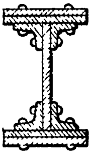


Fig. 150 L

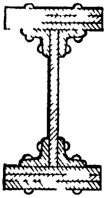


Fig. 150 M

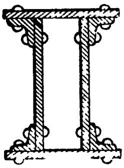


Fig. 150 N

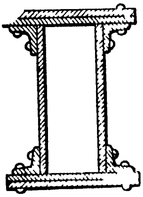


Fig. 150 O

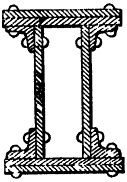


Fig. 150 P

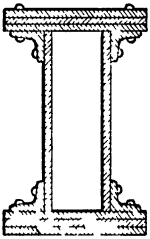


Fig. 150 Q

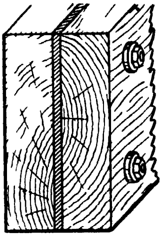


Fig. 150 R

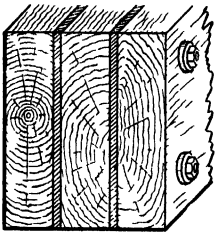


Fig. 150 S

Table 97.—ESTIMATED SAFE PERMANENT DISTRIBUTED LOADS IN TONS ON RIVETED-STEEL GIRDERS, WITH ENDS FIRMLY FIXED

Section like Fig	Depth of Girder and Breadth of Flanges in Inches	Weight of the Girder per Foot in Length	LENGTH OF THE CLEAR SPAN OF THE GIRDER IN FEET					
			12 Feet	16 Feet	18 Feet	20 Feet	24 Feet	30 Feet
	Depth Breadth	lbs.	Tons	Tons	Tons	Tons	Tons	Tons
150 J	9 × $6\frac{3}{8}$	46	16					
150 K	12 × 9	90	42	31	28	25	21	
150 L	18 × 10	138	106	80	71	64	53	42
150 M	24 × 12	208	220	165	147	130	110	88
150 N	18 × 16	140	88	66	58	54	44	35
150 O	24 × 16	216	232	174	154	140	116	96
150 P	21 × 18	224	200	150	133	120	100	80
150 Q	30 × 18	316	416	312	222	250	210	166

The loads in the above Table are approximately equal to one-third of the breaking loads.

Table 97A.—Estimated Approximate Breaking Loads uniformly distributed on Flitch-Beams of Timber equal in strength to that of Memel, securely bolted together, and fixed at both Ends. Thickness of Flitch-plates ½ Inch.

Beam with one Flitch-Plate.	Length of the Clear Span of the Beam in Feet.							
Size of Timber.	10 Feet.	12 Feet.	13 Feet.	14 Feet.	15 Feet.	16 Feet.	18 Feet.	20 Feet.
Inches. Inches.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
2 = 8 × 4	24·9	20.8	19·2	17·8	16·6	15·6	13·8	12·4
2 = 9 × 4	31·6	26·3	24·3	22·5	21·0	19·7	17·5	15·7
2 = 10 × 5	45·0	37·5	34·6	31·1	30·0	28·1	25·0	42·5
2 = 11 × 5	54·4	45·3	41·8	38·8	36·3	34·0	30·2	27·2
2 = 12 × 6	73·4	61·2	56·4	52·4	48·9	45·9	40·0	36·7
2 = 14 × 6	100·0	83·3	76·8	71·4	66·6	62·4	55·5	49·9
Beam with two Flitch-Plates.								
3 = 9 × 4	53·4	44·5	41·1	38·1	35·6	33·4	29·7	26·7
3 = 10 × 5	75·0	62·5	57·6	53·5	50·0	46·8	41·6	37·5
3 = 11 × 5	90·7	75·6	69·8	64·8	60·5	56·7	50 4	45·3
3 = 12 × 5	108·0	90·0	83·0	77·1	72·0	67·5	60·0	54·0
3 = 14 × 5	147·0	122·5	113·0	105·0	98·0	91·8	81·6	73·5

The safe permanent distributed loads on flitch-beams should not exceed one-third of the above breaking loads, but it is better rather less.

Table 98.—Estimated Approximate Crushing Loads on Rolled-Steel Joists used as Stanchions, with flat Ends firmly fixed and equally loaded.

Section.	Height of Stanchion in Feet.							
	6 Feet.	7 Feet.	8 Feet.	9 Feet.	10 Feet.	11 Feet.	12 Feet.	14 Feet.
Inches. Inches.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
4 × 3	31·2	29·0	26·8	24·7	22·7			
5 × $4\frac{1}{2}$	69·7	67·2	64·5	61·7	58·9	56·0	53·2	47·6
6 × 5	90·5	88·6	85·7	82·7	79·5	76·3	73·0	66·6
8 × 6	119·5	116·7	113·7	110·5	107·0	103·5	100·0	92·5
9 × 7	215·7	212·4	207·8	203·3	198·5	193 4	188·2	180·4
$9\frac{1}{2}$ × $4\frac{1}{2}$	86·5	83·0	79·4	75·6	71·7	68·0	64·2	57·2
10 × 6	169·6	165·4	160·8	156·0	150·8	145·5	140·1	129·2
12 × 6	181·6	177·3	172 6	167·6	161·3	156·7	151·3	140·0
12 × $6\frac{1}{2}$	234·1	228·8	223·1	216·9	210·3	203·6	196·7	182·6
$13\frac{13}{16}$ × $5\frac{1}{2}$	185·1	179·4	173 3	166·7	160·0	153·2	146·4	133·0
$15\frac{3}{4}$ × $6\frac{3}{32}$	257·3	250·4	242·0	235·0	226·9	218·4	209·7	192·7

The working load on stanchions should not exceed one-fifth for dead loads, or one-seventh for live loads of the above crushing loads but it is better rather less.

Table 98.—WEIGHT AND VOLUME OF METALS.

	Wrought Iron, Rolled.	Wrought Iron, Forged.	Cast Iron.	Bessemer Steel.	Rolled Steel.	Copper.	Brass.	Lead.	Water.
Weight of one cubic foot . . . lbs.	480	487	450	492	490	549	525	710	62·4
Weight of one cubic inch . . . . lbs.	·278	·282	·26	·285	·283	·318	·304	·41	·036
Number of cubic inches in one lb. .	3·6	3·55	3·84	3·51	3·53	3·15	3·29	2·43	27·7
Weight of one square foot one inch thick . . . . lbs.	40	40·6	37·5	41	40·8	46	43	59	5·2
Weight of one cylindrical foot . lbs.	377	382	355	386	385	431	412	557	49
Weight of one cylindrical inch . lbs.	·218	·221	·205	·223	·222	·249	·238	·323	·028
Number of cylindrical inches in one lb.	4·6	4·5	4·8	4·47	4·5	4·0	4·19	3·10	35·15
Weight of one circular foot one inch thick . . . . lbs.	31·41	31·84	29·7	32·2	32·05	35·95	34·36	46·42	4·1
Weight of one spherical foot (ball one foot diameter) . . . . . lbs.	251	255	236	258	257	288	275	372	32·73
Weight of one spherical inch . . lbs.	·145	·147	137	·150	·149	·167	·159	·215	·019
Number of spherical inches in one lb. .	6·9	6·78	7·26	6·7	6·74	6·0	6·3	4·65	52·9
Weight of a one-inch round bar one foot long . . . . lbs.	2·63	2·66	2·45	2·68	2·67	3·0	2·84	3·8	·341
Weight of a one-inch square bar one foot long . . . . lbs.	3·35	3·39	3·15	3·45	3·43	3·84	3·65	5·	·434
Number of cubic feet in one ton . .	4·67	4·6	4·98	4·55	4·59	4·08	4·28	3·15	36
Diameter of a ball to weigh one ton . . . . . . inches	25	24¾	25½	24½	24⅝	23¾	24	21¾	

RULES FOR FINDING THE WEIGHTS OF CASTINGS, ETC.

To find the weight of iron castings, multiply the width in quarter inches by the thickness in eighths of an inch, or *vice versa,* and divide the product by 10; then multiply the result by the length in feet, which will give the weight in lbs. of that casting. For wrought iron, add $\frac{1}{20}$ to the result; for lead, add $\frac{1}{2}$; for brass, add $\frac{1}{7}$; and for copper, add $\frac{1}{6}$ to the result.

To find the weight in lbs. of flat castings and bars, multiply the width in inches by the thickness in inches; then multiply by the length in feet, and next by one of the following multipliers, viz.: for cast iron, 3·156 or $3\frac{1}{7}$; for wrought iron, 3·312 or $3\frac{1}{3}$; for lead, 4·854; for brass, 3·644; for copper, 3·87; for steel, 3·4.

To find the weight in lbs. of round plates and bars of cast iron, multiply the square of the diameter in inches by ·7854, then multiply the product by the depth or length in inches, and multiply the result by ·26.

To find the weight in lbs. of a square plate or bar, multiply the square of one of its sides in inches by the thickness in inches, and multiply the product by ·26 for cast iron; for wrought iron, multiply by ·28, and for steel, multiply by ·283.

To find the weight in lbs. of pipes, tubes, and cylinders, subtract the square of the inside diameter in inches from the square of the outside diameter in inches, multiply the result by 7·4, and divide by 3, then multiply by the length of the pipe in feet.

To find the weight in lbs. of a hollow ball or spherical shell, multiply the square of the outside diameter in inches by 3·1416; multiply the product by the thickness of metal in inches, and multiply the result by ·26 for cast iron.

To find the weight in lbs. of the segment of a hollow ball or spherical shell, multiply the outside diameter in inches by 3·1416, and multiply the product by the height of segment, multiply that product by the thickness of metal in inches, and multiply the result by ·26 for cast iron.

To find the weight in lbs. of a cast iron ball, multiply the cube of the diameter in inches by ·137. The weight in lbs. of balls of any metal may be found thus:—multiply the cube of the diameter in inches by ·5236, then multiply the result by the multiplier opposite to the required metal in table 99.

To find the diameter of a ball in inches when the weight in lbs. is given, multiply ·5236 by the multiplier opposite the required metal in table 99, and divide the weight of the ball by the said product, the cube root of the quotient will be the diameter in inches.

To find the weight in lbs. of castings from their cubic contents multiply the cubic contents in inches by the multiplier opposite the metal in the following table.

Table 99.—Multipliers for converting Cubic Inches into Lbs.

Platinum	·77	Steel, rolled	·283
Gold	·70	Cobalt	·282
Mercury	·49	Nickel	·282
Lead	·41	Wrought-iron, forged	·282
Silver	·38	Wrought-iron, rolled	·278
Bismuth	·35	White metal	·270
Copper, sheet	·32	Tin	·268
Copper, cast	·318	Pewter	·261
Phosphor Bronze	·315	Cast-iron	·260
Gun metal	·314	Zinc	·253
Brass wire	·308	Antimony	·241
Brass	·304	Aluminium	·090
Bell metal	·295	Box-wood	·048
White metal for bearings	·290	Teak	·028
Steel, Bessemer	·285	Pine, yellow	·016

Measuring Patterns.—In order to provide against running castings short of metal, moulders in measuring patterns allow 2 lbs. per foot for straining, &c., and take the weight of 1 square foot of cast-iron 1 inch thick at 40 lbs., or 5 lbs. per superficial foot for every ⅛th of an inch thickness of metal. Hence the rule to find the weight in lbs. is—multiply the length in feet by the breadth in feet, and by 5, and by the number of ⅛ths of an inch the metal is thick. In measuring cores, the same rule is used, but instead of multiplying by 5, multiply by 4·7, because 40 lbs. per square foot 1 inch thick, is too much to take out for cores.

Table 100.—Decimal Approximations, etc.

Cylindrical inches multiplied by ·0004545 = cubic feet.
Cylindrical feet multiplied by ·02909 = cubic yards.
Circular inches multiplied by ·00546 = square feet.
Cylindrical inches multiplied by ·2049 = lbs. of cast iron.
Ditto ditto ·22069 = lbs. of hammered wrought-iron
Ditto ditto ·2179 = lbs. of rolled wrought-iron.
Ditto ditto ·2222 = lbs. of steel.
Ditto ditto ·3854 = lbs. of mercury.
Ditto ditto ·2505 = lbs. of copper.
Ditto ditto ·395 = lbs. of lead.
Ditto ditto ·2385 = lbs. of brass.
Ditto ditto ·207 = lbs. of tin.
Ditto ditto ·2042 = lbs. of zinc.
Cubic inches multiplied by ·00058 = cubic feet.
Cubic feet multiplied by ·03705 = cubic yards.
Square inches multiplied by ·007 = square feet.
Avoirdupois lbs. multiplied by ·009 = cwts.
Ditto ditto ·00045 = tons.
Cubic inches divided by 1728 = cubic feet.

Table 101.—MULTIPLIERS FOR CONVERTING THE WEIGHT OF ONE METAL TO THAT OF ANOTHER.

To Convert the Weight in lbs. of the following into .	Rolled Wrought Iron.	Steel.	Cast Iron.	Gun Metal.	Brass.	Copper.	Tin.	Lead.	Zinc.
Wrought iron, rolled, multiply by . .	...	1·026	·95	1·15	1·1	1·152	·95	1·5	·93
Wrought iron, forged do. . .	·988	1·012	·938	1·12	1·08	1·13	·938	1·46	·911
Steel . . . . do. . .	·974	...	·929	1·12	1·07	1·12	·931	1·45	·919
Cast iron . . . do. . .	1·05	1·08	...	1·2	1·155	1·21	1·004	1·56	·988
Gun metal . . do. . .	·88	·90	·83	...	·96	1·00	·83	1·30	·830
Brass . . . . do. . .	·915	·93	·86	1·04	...	1·05	·86	1·35	·856
Copper . . . do. . .	·87	·89	·83	·99	·95	...	·83	1·30	·806
Tin . . . . . do. . .	1·05	1·08	1·00	1·20	1·15	1·21	...	1·56	·986
Lead . . . . do. . .	·67	·69	·64	·77	·74	·775	·644	...	·635
Zinc . . . . do. . .	1·07	1·09	1·02	1·21	1·17	1·223	1·015	1·59	...
Pattern in yellow pine do. . .	17·00	17·02	16·00	19·00	18·8	19·30	16·00	24·00	15·8
Pattern in modelling clay do. . .	4·05	4·125	3·85	4·60	4·44	4·65	3·86	6·00	3·85

Examples of the use of this table.—Example 1 : a wrought-iron shaft-forging weighs 3 cwts., required the weight of a similar shaft of steel : then 3 × 1·012 = 3·036 cwts. Example 2 : a cast-iron plate weighs 50 lbs., required the weight of a gun-metal plate of the same size : then 50 × 1·2 = 60 lbs. Example 3 : required the weight of a cast-iron casting, cast from a solid pattern of yellow-pine weighing 2 cwts. : then 2 × 16 = 32 cwts.

Metal Plates.—The weights of metal plates are given at pages 302, 309, 312, 320.

A solid pattern, without cores, weighing 1 lb., made of yellow pine, will weigh, when cast in cast iron, 16 lbs.; in zinc, 15·8 lbs.; in tin, 16 lbs.; in steel, 17·02 lbs.; in brass, 18·8 lbs.; in gun metal, 19 lbs.; in copper, 19·3 lbs.; in lead, 24 lbs.

The Cone.—To find the solidity or cubic contents of a cone: multiply the area of the base by one-third of the perpendicular height. To find the convex surface of a cone, multiply the circumference of the base by one half the slant height; to which add the area of the base for the whole surface.

To find the surface of the frustrum of a cone: multiply the sum of the perimeters of the two ends by half the slant height, and add the areas of the ends.

To find the cubic contents of a frustrum of a cone, add together the areas of the two ends and the mean proportional between them (that is, the square root of their product), and multiply the sum by one-third of the perpendicular height.

To find the cubic contents of a wedge: to twice the length of the base add the length of the edge; multiply the sum by the breadth of base, and by one-sixth of the height.

To find the surface of a sphere or ball: multiply the square of the diameter by 3·1416.

To find the cubic contents of a sphere: multiply the cube of the diameter by ·5236.

To find the surface of a segment of a sphere: multiply the diameter of the sphere by 3·1416, and then by the height of segment.

To find the cubic contents of the segment of a sphere: from three times the diameter of the sphere, subtract twice the height of segment, then multiply the difference, by the square of the height and by ·5236.

To find the surface of a cylinder: multiply the circumference by the length for the convex surface, to which add twice the area of one end, for its whole surface.

To find the cubic contents of a cylinder: multiply the area of one end by the length.

To find the cubic contents of a parallelopiped: multiply the length by the breadth, and multiply that product by the depth.

To find the surface of a parallelopiped: add the depth to the breadth and multiply by the length, to which add the area of the end.

To find the area of a ring included between the circumference of two concentric circles: multiply the sum of the diameters, by their difference, and by ·7854.

Strength of Cast Iron Pillars or Columns.—The following are rules for columns:

W = the breaking weight in tons; A, the sectional area of the material in inches; R, the ratio of the length to the diameter, the least diameter of the section being taken.

For solid or hollow cast iron columns

$$W = \frac{36a}{1 + \frac{R^2}{400}}.$$

For solid or hollow rectangular cast iron columns

$$W = \frac{36a}{1 + \frac{R^2}{500}}.$$

Table 102.—Safe Load on Hollow Cast-Iron Pillars.

External Diameter.	Thickness of Metal.	Length of Pillar in Feet.									
		8		10		12		14		16	
Inches.	Inches.	Tons	Cwts.	Tons	Cwts.	Tons	Cwts.	Tons	Cwts.	Tons	Cwts.
3	½	3	17	2	18	2	0	1	6	1	1
3½	⅝	6	16	5	0	3	18	2	18	2	1
4	⅝	8	19	6	19	5	3	4	0	3	5
4½	¾	14	4	11	2	8	5	6	17	5	15
5	¾	18	6	14	4	11	3	8	16	7	2
5	1	23	2	18	2	14	4	11	5	9	1
5½	1	27	3	22	18	18	6	14	19	12	0
6	⅝	22	18	18	16	15	1	12	3	10	0
6	¾	26	18	21	19	17	19	14	15	12	0
6½	1	40	0	33	2	27	16	22	3	19	0
7	1	45	18	38	17	32	16	27	3	23	0
7	1¼	55	5	46	11	39	4	33	0	28	0
7½	1	51	18	44	5	37	18	32	0	27	3
8	1	58	0	50	3	43	6	37	3	32	0
8	1¼	70	0	60	0	51	0	45	0	38	10
8½	1	64	0	56	4	49	3	42	12	37	0
9	1	70	0	62	0	54	18	47	16	41	17
9	1¼	83	0	74	0	65	0	57	0	50	0
10	1¼	100	0	90	10	81	0	70	0	60	0

The Loads given in the Table, are for hollow cast iron pillars with flat ends, and securely fixed.

Hollow columns fail principally from crushing, when the length does not exceed thirty times the diameter.

Cast-iron of average quality is crushed with . .	42	Tons per square inch.
Wrought-iron „ „ „	16	
Wrought-iron is permanently injured when crushed with	12	
Oak is crushed with	4	
Deal is crushed with	2	

Columns with both ends round are only ⅓rd, and columns with one end flat, and the other end round only ⅔rds, the strength of columns with both ends flat.

The strength of a column of a cruciform section is only ½, and of a double flanged section only $\frac{3}{4}$, that of a round hollow column, of equal weight.

In contracts for columns, a variation of from $\frac{1}{16}$ to $\frac{3}{32}$ inch in the thickness of metal is permitted in most cases.

Table 103.—PROPORTIONS OF RIVETS AND OF SINGLE AND DOUBLE-RIVETED JOINTS FOR WROUGHT-IRON PLATES.

Thickness of Iron Plate.	Diameter of Iron Rivet.	Length of Rivet from under the Head.	PITCH OF RIVETS, IN INCHES.		BREADTH OF LAP.		Distance of each line of Rivets from each edge of Plate in the Double-Riveted Joint.
			Single-Riveted Joint.	Double-Riveted Zigzag Joint. Pitch along one Line.	Single-Riveted Joint.	Double-Riveted Joint.	
Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
$\frac{3}{16}$	$\frac{3}{8}$	1	$1\frac{1}{8}$	$1\frac{5}{8}$	$1\frac{1}{4}$	$2\frac{1}{4}$	$\frac{11}{16}$
$\frac{1}{4}$	$\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$1\frac{5}{8}$	3	$\frac{7}{8}$
$\frac{5}{16}$	$\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{3}{4}$	$2\frac{1}{2}$	2	$3\frac{5}{8}$	$1\frac{1}{16}$
$\frac{3}{8}$	$\frac{3}{4}$	$1\frac{7}{8}$	$1\frac{7}{8}$	3	$2\frac{1}{4}$	$4\frac{1}{2}$	$1\frac{5}{16}$
$\frac{7}{16}$	$\frac{3}{4}$	$2\frac{1}{8}$	2	$3\frac{1}{4}$	$2\frac{3}{8}$	$4\frac{1}{2}$	$1\frac{5}{16}$
$\frac{1}{2}$	$\frac{13}{16}$	$2\frac{1}{4}$	$2\frac{1}{8}$	$3\frac{3}{8}$	$2\frac{5}{8}$	$4\frac{7}{8}$	$1\frac{3}{8}$
$\frac{9}{16}$	$\frac{7}{8}$	$2\frac{5}{8}$	$2\frac{1}{4}$	$3\frac{1}{2}$	$2\frac{3}{4}$	$5\frac{1}{4}$	$1\frac{1}{2}$
$\frac{5}{8}$	$\frac{7}{8}$	3	$2\frac{3}{8}$	$3\frac{5}{8}$	$2\frac{7}{8}$	$5\frac{1}{4}$	$1\frac{1}{2}$
$\frac{3}{4}$	1	$3\frac{1}{4}$	$2\frac{1}{2}$	$3\frac{3}{4}$	$3\frac{1}{4}$	6	$1\frac{3}{4}$
$\frac{7}{8}$	$1\frac{1}{8}$	$3\frac{1}{2}$	$2\frac{3}{4}$	4	$3\frac{5}{8}$	$6\frac{3}{4}$	$1\frac{15}{16}$
1	$1\frac{1}{4}$	$4\frac{1}{4}$	3	$4\frac{1}{2}$	4	$7\frac{1}{2}$	$2\frac{1}{8}$

In Zigzag Riveting, the rivets in one line divide the spaces between the rivets in the other line, as shown in Fig. 141, page 186. The distance between the rivet-hole and the edge of the plate, or between two rivet-holes, should never be less than the diameter of the rivet.

Proportions of Rivets.—A pan-shaped rivet-head should equal in diameter $1\frac{5}{8}$, and in thickness $\frac{3}{4}$ the diameter of rivet; and when a cup or snap shape, the diameter of rivet head should equal $1\frac{3}{4}$, and the depth $\frac{3}{4}$ the diameter of rivet. The diameter of a conical rivet-head should equal twice, and the depth $\frac{3}{4}$ the diameter of the rivet. The diameter of the head of a countersunk rivet should equal $1\frac{1}{2}$ times, and the thickness $\frac{1}{2}$ the diameter of the rivet. The length of rivet required to form the rivet-head is equal to the diameter of the rivet for countersunk heads, and to $1\frac{1}{4}$ times the diameter for cup and conical rivet-heads.

All Rivet Holes should be perfectly fair with each other, those that are not fair should be rhymed out until they become so—drifting should not be permitted. The rivets should completely fill the holes—which should be slightly countersunk under the rivet-heads,—and the rivet-heads should be true and central. When the rivet holes are drilled in "place" the plates should be taken apart and the burr removed, as it prevents the plates closing tightly to make a good joint.

The Edges of the Plates—in best work—should be planed to an angle of 1 in 8, so as to have a full edge for caulking, which should be done with a broad-faced fuller, so as not to injure the plates.

Butt Strips should be of as good a quality as the plates they cover, and should be cut from plates and not from bars. Single butt strips should be ⅛ inch thicker than the plates they cover, and double butt strips should each be not less than ⅝ the thickness of the plates they cover. Butt strips for the longitudinal seams of boiler should be cut across the fibre.

Strength of Riveted-Joints.—The percentage of strength of the *plate* at the joint as compared with the solid plate may be found by the following rule :—

$$\frac{(\text{Pitch} - \text{diameter of rivets}) \times 100}{\text{Pitch of rivets}}$$

The percentage of strength of the *rivets* as compared with the solid plate may be found by the following rule :—(For other Rules, see page 184),

$$\frac{(\text{Area of rivets} \times \text{number of rows of rivets}) \times 100}{\text{Pitch of rivets} \times \text{thickness of plate}}$$

The Proportions of Riveted joints in Mild Steel Plates that can be recommended for use in general constructional work are as follows :

In single riveted-joints the shearing resistance of rivet-steel is about 22 tons per square inch. So long as the bearing pressure on the rivets does not exceed 43 tons per square inch, measured on the projected area of the rivets, it does not affect their strength : but pressure of 50 to 55 tons cause the rivets to shear at stresses of from 16 to 18 tons per square inch.

For Single Riveted Lap-Joints, the diameter of the rivet-hole should be 2⅓ times the thickness of the plate and the pitch of the rivets 2⅜ times the diameter of the rivet-hole, this makes the plate-area 71 per cent. of the rivet area. For any other size of rivet-hole the pitch $p = 0{\cdot}56\frac{d^2}{t} + d$, where d is the diameter of the rivet-hole, and t is the thickness of the steel plate in inches.

For Double Riveted Lap-Joints, of any thickness of plate from ⅜ to ¾ inch, with rivets as large as possible :—

For 30-ton plate and 24-ton rivets
,, 28 ,, 22 ,, $\Big\}\; p = 1{\cdot}16\frac{d^2}{t} + d$

,, 30 ,, 22 ,, $p = 1{\cdot}06\frac{d^2}{t} + d$

,, 28 ,, 24 ,, $p = 1{\cdot}24\frac{d^2}{t} + d.$

NOTE.—As the plate is more affected by time than the rivets, it is advisable to estimate the percentage by which the plates may be weakened by corrosion, &c., before the boiler would be unfit for use at its proper steam pressure, and to add correspondingly to the plate-area. This may be effected by proportioning the joint, not for the actual thickness of the plate, but for a nominal thickness less than the actual by the assumed percentage.

For Double Riveted Butt-Joints the maximum strength is obtained by making the pitch $= 4{\cdot}1$ times the diameter of rivet-hole, and the diameter of the rivet-hole $= 1{\cdot}8$ times the thickness of the plate. The above rules only refer to joints made in soft steel plates—unannealed—with steel rivets.

Table 104.—WEIGHT OF A SQUARE FOOT OF SHEET-IRON AND OF WROUGHT-IRON BOILER PLATES, ETC.

Thickness, in inches . .	$\frac{1}{32}$	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4
Weight of a piece twelve inches square, in lbs. .	$1\frac{1}{4}$	$2\frac{1}{2}$	5	$7\frac{1}{2}$	10	$12\frac{1}{2}$	15	$17\frac{1}{2}$	20	$22\frac{1}{2}$	25	$27\frac{1}{2}$	30	$32\frac{1}{2}$	35	$37\frac{1}{2}$	40	45	50	55	60	70	75	80	100	120	140	160

Steel Boiler-Plates weigh 1·28 lbs. per square foot $\frac{1}{32}$ inch thick, hence the rule to find the weight in lbs. of a steel plate is:—Multiply the length in feet by the breadth in feet, and by 1·28, and multiply the product by the number of $\frac{1}{32}$ds of an inch the plate is thick. For the weight of steel-plates, per square foot, to the new imperial standard wire gauge, see page 311.

Table 105.—WEIGHT OF CIRCULAR WROUGHT-IRON PLATES.

Thickness.	Diameter in Inches . . .	12	15	18	21	24	27	30	33	36	42	48	54	60	66	72	78	84	90	96
Inches.																				
$\frac{1}{4}$	Weight in lbs. . .	8	$12\frac{1}{2}$	18	$24\frac{1}{2}$	32	40	50	60	72	98	128	161	200	240	288	336	392	445	512
$\frac{5}{16}$	" " . .	10	16	23	31	40	50	64	75	92	124	160	200	254	300	368	417	496	554	640
$\frac{3}{8}$	" " . .	12	19	27	37	48	60	75	90	108	147	192	242	300	360	432	504	588	667	766
$\frac{7}{16}$	" " . .	14	22	31	42	56	70	88	103	124	168	224	280	352	412	496	578	672	769	896
$\frac{1}{2}$	" " . .	16	25	36	49	64	81	100	120	144	196	256	322	400	480	576	672	784	890	1024
$\frac{5}{8}$	" " . .	20	32	46	62	80	100	128	150	184	248	320	400	508	600	736	834	992	1108	1280
$\frac{3}{4}$	" " . .	24	38	54	73	96	120	150	180	216	294	384	483	600	720	864	1008	1176	1335	1536
$\frac{7}{8}$	" " . .	28	44	62	84	112	140	176	206	248	336	448	560	704	824	992	1170	1344	1538	1792
1	" " . .	32	50	72	98	128	161	200	240	288	392	512	644	800	960	1152	1344	1568	1790	2048
$1\frac{1}{4}$	" " . .	40	63	90	123	160	201	250	300	360	490	640	805	1000	1200	1440	1668	1960	2216	2560
$1\frac{1}{2}$	" " . .	48	75	108	147	192	242	300	360	432	588	768	966	1200	1440	1728	2016	2352	2680	3172

Table 106.—WEIGHT IN LBS. OF 1 DOZEN WHITWORTH'S THREAD IRON BOLTS, WITH HEXAGON HEADS AND NUTS AND ROUND NECKS; ALSO THE WEIGHT THEY WILL SAFELY CARRY, AND THE WEIGHT OF 1 DOZEN IRON WASHERS.

Length of Bolt.	Diameter of Bolt, in Inches.														
	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2
Inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1½	·51	1·3	2·6	4·8	7·4	11·8	17·3								
1¾	·55	1·4	2·7	5·1	7·8	12·4	18	27							
2	·61	1·6	2·9	5·3	8·2	12·9	19	28	34						
2½	·71	1·7	3·3	5·8	8·9	13·9	20	30	36	49					
3	·81	1·9	3·6	6·4	9·7	14·9	21	32	38	51	63				
3½	·91	2·1	3·9	6·9	10·4	15·3	23	33	40	54	66	81			
4	1·02	2·3	4·3	7·4	11·2	17	24	35	42	56	69	85	100		
4½	1·12	2·5	4·6	7·8	11·9	18	25	37	44	59	72	89	104	130	
5	1·22	2·7	5	8·5	12·6	19	27	38	46	61	75	92	108	134	158
5½	1·32	2·9	5·3	9	13·4	20	28	40	48	63	78	96	112	139	164
6	1·4	3·1	5·7	9·5	14·1	21	29	42	50	66	81	99	116	146	169
7	1·6	3·5	6·3	10·5	15·6	23	32	45	55	71	87	106	125	153	179
8	1·8	3·9	7	11·6	17	25	34	48	59	76	92	113	133	162	190
9	2	4·4	7·7	12·6	18·6	27	37	52	63	81	98	120	142	172	200
10	2·3	4·8	8·4	13·6	20·1	29	40	55	67	86	104	127	150	181	212
11	2·5	5·2	9·1	14·7	21·6	31	43	58	71	91	110	134	157	190	224
12	2·7	5·6	9·8	15·7	23	33	46	62	75	94	116	140	166	200	236
Weight of 12 washers, in lbs. . .	·5	·6	·7	·8	1	1·3	2	2·5	4	6	8	9	10	13	16
Thickness of washer, in inches .	1/16	1/16	3/32	⅛	⅛	⅛	3/16	3/16	¼	¼	5/16	5/16	5/16	⅜	7/16
Diameter of washer, in inches .	¾	1	1¼	1½	1¾	2⅛	2¼	2½	2¾	3	3¼	3½	3¾	4	4¼
Working strength or load the bolt will safely carry, in cwts., if made of good iron	1	2½	4	8	12	16	24	28	40	45	55	65	75	85	100

Strength of Bolts.—The average tensile strength of the iron of which bolts are made is 20 tons per square inch, and the safe working load for bolts not subject to much strain, is 4 tons per square inch of area of cross section, at the bottom of the thread. For moderately tightened bolts, 2 tons per square inch; and for bolts, which, carrying a great strain, are liable to stretch after being severely tightened, such as the bolts of steam-joints, 1 ton per square inch of area of cross section, at the bottom of the thread.

Foundation Bolts, having a cotter through one end, should have that end swelled equal to $1\frac{1}{4}$ the diameter of the bar, and the cotter should equal $1\frac{1}{4}$ in depth and $\frac{1}{4}$ in thickness the diameter of the bar. Long bolts or tie-rods with screwed ends, should have the ends swelled, to at least the depth of thread of the screw,

Joint with Pin, like Fig. 151.

The diameter of the pin = the diameter of the rod, E.

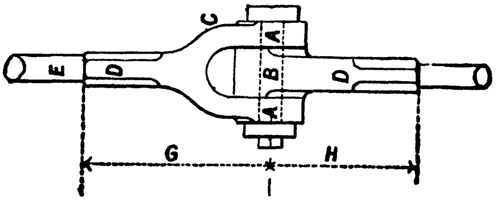


Fig 151.—Fork-Joint.

Width between the fork, B, = 1·25 diameter of the rod. E.
Width of the jaw of fork, A, = ·75 diameter of the rod, E.
Width of the jaw of fork, C, = ·62 diameter of the rod, E.
Width across cants, D, = 1·2 diameter of the rod, E.
Diameter of the boss of the fork = twice the diameter of the pin.
Diameter of the pin head and washer = 1·62 the diameter of the pin.
Thickness of head of pin and washer = one-half the diameter of the pin.
Centre of pin to end of cant, G, = $4\frac{1}{2}$ times the diameter of the pin.
Centre of pin to end of cant, H, = $3\frac{1}{2}$ times the diameter of the pin.

Lock-Nuts should be equal in thickness to half the diameter of the bolt.

Squar eNuts should have the same width across the flats as hexagon nuts. In confined spaces, both the head and nut are each made, in thickness, $\frac{5}{8}$ths of the diameter of the bolt. It has been found that a well fitted nut, equal in thickness to $\frac{3}{4}$ths the diameter of the bolt, will not strip before the bolt breaks.

A Screw-Key or Spanner for Nuts should have the end bent at an angle of 15° with the centre-line of the handle. The ends of screw-keys are frequently bent at an angle of 30°. The length of a screw-key, from end to end, is generally equal to from 7 to 12 times the width between the jaws of the screw-key.

Table 107.—Size of Whitworth's Standard Hexagon Nuts.

Size of Nuts.	Diameter of Bottom of Thread.	Width Across Corners.	Width of Nut across the Flats.		Size of Nut.	Diameter of Bottom of Thread.	Width Across Corners.	Width of Nut across the Flats.	
			Exact Size.	Nearest Size.				Exact Size.	Nearest Size.
Inch.	Inches.	Inches.	Inches.	Inches.	Inch.	Inches.	Inches.	Inches.	Inches.
$\frac{3}{16}$	·134	·517	·448	$\frac{7}{16}$ and $\frac{1}{32}$	$1\frac{1}{4}$	1·067	2·365	2·048	$2\frac{1}{32}$
$\frac{1}{4}$	·186	·606	·525	$\frac{1}{2}$ and $\frac{1}{32}$	$1\frac{3}{8}$	1·161	2·557	2·215	$2\frac{3}{16}$ and $\frac{1}{32}$
$\frac{5}{16}$	·241	·694	·601	$\frac{5}{8}$	$1\frac{1}{2}$	1·286	2·786	2·413	$2\frac{7}{16}$
$\frac{3}{8}$	·295	·819	·709	$\frac{11}{16}$ and $\frac{1}{32}$	$1\frac{5}{8}$	1·369	2·974	2·576	$2\frac{9}{16}$
$\frac{7}{16}$	·346	·947	·820	$\frac{13}{16}$	$1\frac{3}{4}$	1·494	3·184	2·758	$2\frac{3}{4}$
$\frac{1}{2}$	·393	1·061	·919	$\frac{15}{16}$	$1\frac{7}{8}$	1·590	3·485	3·018	3
$\frac{9}{16}$	·456	1·167	1·011	$1\frac{1}{32}$	2	1·715	3·636	3·149	$3\frac{1}{8}$ and $\frac{1}{32}$
$\frac{5}{8}$	·508	1·271	1·101	$1\frac{1}{16}$ and $\frac{1}{32}$	$2\frac{1}{8}$	1·840	3·853	3·337	$3\frac{5}{16}$ and $\frac{1}{32}$
$\frac{11}{16}$	·571	1·387	1·201	$1\frac{3}{16}$ and $\frac{1}{32}$	$2\frac{1}{4}$	1·930	4·094	3·546	$3\frac{1}{2}$ and $\frac{1}{32}$
$\frac{3}{4}$	·622	1·502	1·301	$1\frac{5}{16}$	$2\frac{3}{8}$	2·055	4·33	3·75	$3\frac{3}{4}$
$\frac{13}{16}$	·684	1·605	1·39	$1\frac{3}{8}$ and $\frac{1}{32}$	$2\frac{1}{2}$	2·180	4·496	3·894	$3\frac{7}{8}$ and $\frac{1}{32}$
$\frac{7}{8}$	·733	1·707	1·479	$1\frac{7}{16}$ and $\frac{1}{32}$	$2\frac{5}{8}$	2·305	4·675	4·049	$4\frac{1}{16}$
$\frac{15}{16}$	·795	1·8	1·574	$1\frac{9}{16}$	$2\frac{3}{4}$	2·384	4·827	4·181	$4\frac{3}{16}$
1	840	1·928	1·67	$1\frac{11}{16}$	$2\frac{7}{8}$	2·509	5·017	4·346	$4\frac{5}{16}$ and $\frac{1}{32}$
$1\frac{1}{8}$	·942	2·148	1·86	$1\frac{7}{8}$	3	2·634	5·231	4·531	$4\frac{1}{2}$ and $\frac{1}{32}$

Note.—Thickness of Nut equal to the Diameter of the Bolt.

Table 108.—Weights of Gas Tubes and Fittings.

Size.	Tubes.							Fittings.					
	Weight per 100 Feet.			Weight per 1000 Feet.				Weight of 10 Elbows.		Weight of 10 Tees.		Weight of 10 Crosses.	
	cwts.	qrs.	lbs.	tons	cwts.	qrs.	lbs.	lbs.	ozs.	lbs.	ozs.	lbs.	ozs.
$\frac{1}{8}$	0	1	0	0	2	2	0	1	1	1	0	1	8
$\frac{1}{4}$	0	1	14	0	3	3	0	1	7	1	8	1	14
$\frac{3}{8}$	0	2	6	0	5	2	4	1	13	2	4	2	3
$\frac{1}{2}$	0	3	6	0	8	0	4	2	15	3	0	3	4
$\frac{3}{4}$	1	0	22	0	11	3	24	4	6	5	4	5	11
1	1	3	0	0	17	2	0	6	4	7	10	9	2
$1\frac{1}{4}$	2	1	11	1	3	1	26	10	10	12	15	14	11
$1\frac{1}{2}$	2	3	7	1	8	0	14	15	8	16	7	18	10
$1\frac{3}{4}$	3	0	12	1	11	0	8	15	12	20	0	21	4
2	3	3	21	1	19	1	14	22	6	27	0	31	4
$2\frac{1}{4}$	4	0	26	2	2	1	8	30	2	32	8	41	4
$2\frac{1}{2}$	5	0	6	2	10	2	4	46	2	50	15	51	4
$2\frac{3}{4}$	5	1	19	2	14	0	22	55	10	68	8	80	10
3	6	0	20	3	1	3	4	73	8	85	5	88	12
$3\frac{1}{2}$	7	1	14	3	13	3	0	101	0	121	0	129	0
4	8	2	0	4	5	0	0	126	0	144	0	158	0

Table 109.—WEIGHT OF LEAD AND COMPOSITION GAS PIPES.

Diameter Inside.	Light.		Heavy.	
	Weight per Yard.	Lengths of Bundles usually Manufactured.	Weight per Yard.	Lengths of Bundles usually Manufactured.
Inches.	lbs. ozs.	yards.	lbs. ozs.	yards.
¼	0 11½	80	0 15	67
⅜	1 2	60	1 6½	46
½	2 0	32	2 10	29
¾	3 3	23	3 12	19
1	4 8	26	6 0	20

Table 110.—WEIGHT PER YARD, OF BLOCK-TIN TUBES.

Bore.	ozs.	Bore.	lbs. ozs.	Bore.	lbs. ozs.
¼ inch... ...	8	½ inch... ...	1 1	¾ inch... ...	1 14
⅜ „	11	⅝ „	1 7	1 „	2 15

Table 111.—WEIGHT OF GALVANIZED CORRUGATED-IRON SHEETS.

Number of Gauge.	Weight per Square, of 100 feet.			Size of Sheet.
	Old Gauge.	B.G. Sheet Gauge.	New Standard Wire-gauge.	
	cwts. qrs. lbs.	cwts. qrs. lbs.	cwts. qrs. lbs.	
16	3 0 14	3 0 1	3 0 9	6 feet × 2 feet, 2 inches, with five 5-inch corrugations.
18	2 2 11	2 2 9	2 2 0	
20	1 3 6	1 3 2	1 2 14	6 feet × 2 feet 2 inches, with eight 3-inch corrugations.
22	1 2 6	1 2 7	1 1 18	
24	1 1 0	1 0 26	1 0 12	
26	0 3 19	0 3 17	0 3 9	

Table 112.—WEIGHT OF GALVANIZED CORRUGATED IRON SHEETS.

Number of Gauge.	16	18	20	22	24	26	Gauge.
Weight to the old gauge, lbs.	52	34	25	21	16½	12½	Weight in lbs. of each sheet, size 72 in. × 26 in.
Weight to B.G. gauge, lbs.	50	33¾	24½	21⅛	16¼	12¼	
Weight to the new standard wire-gauge, lbs.	51¼	32½	22½	19	14½	11¼	
Square feet per ton, old gauge	640	770	1080	1300	1680	2170	Square feet per ton.
Square feet per ton, B. G. gauge	665	776	1132	1280	1624	2218	
Square feet per ton, standard wire-gauge	650	800	1231	1418	1807	2409	

Table 113.—Weight of 1 Foot in Length of Round and Square, Wrought-Iron and Steel Bars.

Size of Bar, in Inches . . .	1/16	⅛	3/16	¼	5/16	⅜	7/16	½	9/16	⅝	11/16	¾	13/16	⅞	1
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight of round iron .	·01	·042	·093	·168	·26	·36	·50	·65	·83	1·03	1·25	1·47	1·74	2·00	2·63
Weight of round steel .	·011	·043	·095	·17	·28	·38	·52	·68	·86	1·05	1·28	1·51	1·77	2·06	2·68
Weight of square iron .	·0125	·053	·118	·21	·33	·47	·64	·84	1·08	1·31	1·6	1·9.	2·23	2·58	3·35
Weight of square steel .	·014	·056	·121	·23	·35	·50	·67	·87	1·12	1·35	1·64	1·95	2·27	2·65	3·45

Size of Bar, in Inches . . .	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	2⅛	2¼	2⅜	2½	2⅝	2¾	2⅞
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight of round iron .	3·31	4·09	5·	5·89	6·91	8·02	9·21	10·5	11·8	13·3	14·8	16·5	18·1	19·8	21·6
Weight of round steel .	3·37	4·18	5·12	6·06	7·12	8·18	9·43	10·7	12·1	13·6	15·1	16·7	18·5	20·2	22·
Weight of square iron .	4·25	5·25	6·33	7·5	8·8	10·2	11·7	13·33	15·1	16·9	18·8	20·8	23·	25·2	27·6
Weight of square steel .	4·35	5·36	6·48	7·7	8·94	10·47	11·96	13·68	15·5	17·3	19·27	21·3	23·6	25·9	28·3

Size of Bar, in Inches . . .	3	3⅛	3¼	3⅜	3½	3⅝	3¾	3⅞	4	4⅛	4¼	4⅜	4½	4¾	5
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight of round iron .	23·6	25·6	27·7	30·	32·2	34·5	37·	39·3	42·	45	47	50	53·2	59·5	66·
Weight of round steel .	24·1	26·3	28·3	30·6	32·8	35·2	37·7	40·	42·7	47	49	52	54·7	60·5	67·
Weight of square iron .	30·	32·6	35·2	38·	40·8	44·	46·9	50·	53·3	56	61	64	67·5	75·2	83·3
Weight of square steel .	30·8	33·4	36·1	38·9	41·7	45·	47·9	51·1	54·5	58	64	67	69·	76·9	85·

Size of Bar, in Inches . . .	5¼	5½	5¾	6	6¼	6½	7	7½	8	8½	9	10	11	12	13
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight of round iron .	72·6	80·	87·	95·	102	111	130	148	168	190	213	264	319	380	445
Weight of round steel .	73·7	81·5	88·7	96·7	104	113	132	151	171	194	217	267	325	387	453
Weight of square iron .	92·	101·	111·	120·	131	141	164	190	215	243	272	336	407	485	560
Weight of square steel .	93·9	103·	114·	124·	135	146	169	196	222	250	284	348	420	498	575

Table 114.—WEIGHT OF 1 FOOT IN LENGTH OF FLAT WROUGHT-IRON AND STEEL BARS, HOOP IRON AND CHISEL STEEL.

Flat Bars, Size in Inches . .	1 × ¼	1 × ⅜	1¼ × ⅜	1¼ × ½	1½ × ⅜	1½ × ½	1¾ × ⅜	1¾ × ½	2 × ½	2 × ⅝	2¼ × ½	2¼ × ¾	2½ × ½	2½ × ¾	2¾ × ½
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight of flat iron . .	·84	1·3	1·58	2·1	1·9	2·5	2·2	2·95	3·35	4·2	3·8	5·7	4·2	6·3	4·6
Weight of flat steel . .	·86	1·33	1·62	2·15	1·94	2·56	2·25	2·99	3·43	4·28	3·85	5·78	4·28	6·40	4·70

Flat Bars, Size in Inches . .	2¾ × ¾	3 × ½	3 × ¾	3½ × ¾	3½ × 1	4 × ¾	4 × 1¼	4½ × ¾	4½ × 1¼	5 × ¾	5 × 1¼	6 × 1	6 × 1½	7 × 1½	7 × 3
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight of flat iron . .	6·9	5·	7·5	8·8	11·8	10·1	16·7	11·4	19·0	12·6	21·	20·2	30·3	35	70
Weight of flat steel . .	7·1	5·16	7·7	9·0	11·96	10·28	17·1	11·58	19·2	12·9	21·3	20·5	30·7	36	72
Hoop Iron. Width in inches			¾	⅞	1	1⅛	1¼	1½	1¾	2	2¼	2½	3	3½	4
Hoop Iron. Thickness, number of gauge . .			20	19	18	17	16	15	14	13	13	12	11	9	7
Hoop Iron. Weight to the **B.G.** hoop gauge, lbs.			·092	·125	·166	·190	·250	·350	·473	·621	·697	·882	1·10	1·81	2·52
Hoop Iron. Weight to the standard wire-gauge, lbs.			·085	·114	·161	·192	·256	·360	·482	·646	·727	·930	1·24	1·87	2·51
Chisel Steel. Hexagon. Size across flats, in inches							½	⅝	¾	⅞	1	1⅛	1¼		
Chisel Steel. Weight, in lbs.							·75	1·2	1·7	2·3	3·	3·8	4·7		
Chisel Steel. Flat oval section. Size, in inches							¾ × ⅜ = ·9 lbs.: 1 × ½ = 1·6 lbs.: 1¼ × ⅝ = 2·45 lbs.								

Table 115.—WEIGHT OF 100 FEET IN LENGTH OF IRON AND STEEL WIRE.

Thickness by the New Standard W. G. . . .	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Weight of 100 feet in length of iron wire	·40	·60	·80	1·06	1·33	1·66	2·16	2·8	3·47	4·23	5·34	6·60	8·0	9·5	11·6	13·9	16·4	19·7	23·2
Weight of 100 feet in length of steel wire . . .	·41	·61	·82	1·08	1·40	1·69	2·19	2·11	3·51	4·28	5·40	6·67	8·9	9·6	11·7	14·0	16·5	19·9	23·5

Table 116.—WEIGHT OF 12 INCHES SQUARE OF ROLLED WROUGHT-IRON PLATES AND SHEET-IRON.

Number of Gauge.	Weight per Square Foot to the Sheet and Hoop-Iron B. G. Gauge.		Weight per Square Foot to the new Imperial Standard Wire-Gauge.		Number of Gauge.	Weight per Square Foot to the Sheet and Hoop-Iron B. G. Gauge.		Weight per Square Foot to the new Imperial Standard Wire-Gauge.	
	lbs.	Thickness. Inch.	lbs.	Thickness. Inch.		lbs.	Thickness. Inch.	lbs.	Thickness. Inch.
7/0	26·67	·6666	20·00	·500	22	1·25	·0312	1·12	·028
6/0	25·00	·6250	18·56	·464	23	1·11	·0278	·96	·024
5/0	23·54	·5883	17·28	·432	24	·99	·0247	·88	·022
4/0	21·67	·5416	16·00	·400	25	·88	·0220	·80	·020
3/0	20·00	·5000	14·88	·372	26	·785	·0196	·72	·018
2/0	17·8	·4452	13·92	·348	27	·700	·0174	·65	·0164
1/0	15·8	·3964	...	...	28	·625	·0156	·59	·0148
0	...	...	13·0	·324	29	·557	·0139	·54	·0136
1	14·1	·3532	12·0	·300	30	·493	·0123	·495	·0124
2	12·6	·3147	11·04	·276	31	·440	·0110	·464	·0116
3	11·2	·2804	10·10	·252	32	·392	·0098	·432	·0108
4	10·0	·2500	9·25	·232	33	·348	·0087	·400	·0100
5	8·9	·2225	8·50	·212	34	·308	·0077	·368	·0092
6	7·95	·1981	7·70	·192	35	·276	·0069	·336	·0084
7	7·05	·1764	7·05	·176	36	·245	·0061	·304	·0076
8	6·30	·1570	6·40	·160	37	·216	·0054	·272	·0068
9	5·57	·1398	5·75	·144	38	·192	·0048	·240	·0060
10	5·00	·1250	5·10	·128	39	·172	·0043	·208	·0052
11	4·44	·1113	4·64	·116	40	·154	·00386	·192	·0048
12	3·87	·0991	4·16	·104	41	·138	·00343	·176	·0044
13	3·53	·0882	3·68	·092	42	·123	·00306	·160	·0040
14	3·14	·0785	3·20	·080	43	·109	·00272	·144	·0036
15	2·76	·0699	2·87	·072	44	·097	·00242	·128	·0032
16	2·50	·0625	2·55	·064	45	·086	·00215	·112	·0028
17	2·22	·0556	2·30	·056	46	·077	·00192	·096	·0024
18	1·97	·0495	1·91	·048	47	·068	·00170	·080	·0020
19	1·76	·0440	1·60	·040	48	·061	·00152	·064	·0016
20	1·57	·0392	1·44	·036	49	·054	·00135	·048	·0012
21	1·40	·0349	1·28	·032	50	·048	·00120	·040	·0010

WEIGHT OF SIEMENS' MILD-STEEL BOILER-PLATES.

	In.		Ft.	In.		Ft.			Cwt.	Qrs.	Lbs.
Steel-plate	$\frac{3}{8}$	thick,	3	0	wide, and	23	long,	weighs	9	1	21
Ditto	$\frac{7}{16}$	,,	3	6	,,	24	,,	,,	13	1	16
Ditto	$\frac{1}{2}$	,,	3	9	,,	25	,,	,,	17	0	10
Ditto	$\frac{9}{16}$	,,	4	0	,,	26	,,	,,	21	1	9
Ditto	$\frac{5}{8}$	,,	4	6	,,	27	,,	,,	27	2	21
Ditto	$\frac{11}{16}$	,,	5	0	,,	28	..	,,	35	0	10
Ditto	$\frac{3}{4}$	,,	6	0	,,	30	,,	,,	49	0	25

Table 117.—WEIGHT OF 12 INCHES SQUARE OF ROLLED SHEET-COPPER AND SHEET-BRASS IN LBS. AND OUNCES, AND ALSO IN LBS. AND DECIMAL PARTS; THE THICKNESS BEING MEASURED BY THE NEW IMPERIAL STANDARD WIRE-GAUGE.

Thickness by Number of the New Standard Wire-Gauge.	SHEET-COPPER.			SHEET-BRASS.		
	Weight in lbs. and ounces.		Weight in lbs. and Decimal parts of a lb.	Weight in lbs. and ounces.		Weight in lbs. and Decimal parts of a lb.
	lbs.	ozs.	lbs.	lbs.	ozs.	lbs.
7/0	23	4	23·250	21	9	21·57
6/0	21	9¼	21·578	19	15½	19·97
5/0	20	1¼	20·078	18	9½	18·59
4/0	18	9½	18·594	17	3½	17·22
3/0	17	4½	17·282	16	0¼	16·01
2/0	16	3	16·188	14	15¾	14·98
0	15	1	15·063	13	15½	13·95
1	13	15¼	13·954	12	15	12·92
2	12	13¼	12·828	11	14	11·87
3	11	11½	11·719	10	13½	10·84
4	10	12½	10·782	10	0	10·00
5	9	13¾	9·860	9	2	9·12
6	8	14½	8·907	8	4¼	8·26
7	8	3	8·188	7	9¼	7·57
8	7	7	7·438	6	14¾	6·88
9	6	11	6·688	6	3½	6·21
10	5	15¼	5·954	5	8¼	5·51
11	5	6¼	5·391	5	0	5·00
12	4	13¼	4·828	4	7¾	4·48
13	4	4½	4·282	3	15½	3·96
14	3	11½	3·719	3	7	3·44
15	3	5½	3·344	3	1¾	3·10
16	3	0	3·000	2	12¼	2·76
17	2	9½	2·594	2	6¾	2·41
18	2	4	2·250	2	1¼	2·07
19	1	13¾	1·860	1	11¾	1·72
20	1	10¾	1·672	1	8¾	1·55
21	1	7¾	1·485	1	6¼	1·38
22	1	4¾	1·297	1	3½	1·21
23	1	1¾	1·110	1	0¾	1·04
24	1	0⅜	1·024	0	15¼	0·95

Thickness by Number of the new Standard Wire-Gauge.	SHEET-COPPER.	SHEET-BRASS.
	Weight in ounces and Decimal parts of an ounce.	Weight in ounces and Decimal parts of an ounce.
	Ounces.	Ounces.
25	14·93	13·74
26	13·03	12·10
27	12·02	11·16
28	11·00	10·12
29	10·01	9·28
30	9·02	8·30
31	8·63	7·94
32	8·03	7·39
33	7·44	5·36
34	6·84	6·30
35	6·24	5·75
36	5·65	5·21
37	5·05	4·65
38	4·46	4·10
39	3·86	3·56
40	3·57	3·29
41	3·27	3·10
42	2·97	2·73
43	2·67	2·46
44	2·38	2·19
45	2·08	1·92
46	1·78	1·64
47	1·48	1·37
48	1·19	1·10
49	0·89	0·82
50	0·74	0·68

For kilogrammes per square m tre, divide the weight of copper in pounds per square foot by ·205.

Sheet-Copper weighs approximately ¾ ounce per $\frac{1}{1000}$ inch per square foot. Therefore to find the weight of sheet copper when in stated decimals of an inch, subtract one-fourth of the number of thousands of an inch. For instance, the weight of a sheet of copper ·064 inch thick is = ·064 ÷ 4 = ·016, and ·064 − ·016 = 48 ounces per square foot. To find the thickness in thousands of an inch, add one-third to the number of ounces per square foot. For instance, the thickness of a plate weighing 48 ounces per square foot is = 48 ÷ 3 = 16, and 48 + 16 = 64, and = ·064 thousands.

Table 118.—WEIGHT OF 12 INCHES SQUARE OF BESSEMER STEEL, AND ROLLED STEEL SHEETS, AND GUN METAL PLATES; THE THICKNESS BEING MEASURED BY THE NEW IMPERIAL STANDARD WIRE-GAUGE.

Thickness by Number of the New Standard W. G.*	WEIGHT IN LBS.			Thickness by Number of the New Standard W. G.*	WEIGHT IN LBS.		
	Bessemer Steel.	Rolled Steel.	Gun Metal.		Bessemer Steel.	Rolled Steel.	Gun Metal.
7/0	20·50	20·40	22·00	11	4·76	4·74	5·11
6/0	19·03	18·94	20·42	12	4·27	4·25	4·58
5/0	18·72	17·63	19·00	13	3·78	3·76	4·05
4/0	16·40	16·32	17·60	14	3·29	3·27	3·52
3/0	15·25	15·18	16·37	15	2·96	2·94	3·17
2/0	14·27	14·20	15·32	16	2·63	2·61	2·82
0	13·29	13·22	14·26	17	2·30	2·28	2·47
1	12·30	12·24	13·20	18	1·97	1·96	2·12
2	11·32	11·27	12·15	19	1·65	1·64	1·76
3	10·34	10·28	11·09	20	1·48	1·47	1·59
4	9·52	9·47	10·21	21	1·32	1·31	1·41
5	8·70	8·65	9·33	22	1·15	1·14	1·24
6	7·88	7·84	8·49	23	·99	·98	1·06
7	7·22	7·18	7·75	24	·91	·90	·97
8	6·56	6·53	7·04	25	·82	·81	·88
9	5·91	5·88	6·34	26	·74	·73	·79
10	5·25	5·23	5·64	27	·68	·67	·72

Table 119.—WEIGHT OF 12 INCHES SQUARE OF ROLLED WHITE METAL, LEAD, AND ZINC SHEETS; THE THICKNESS BEING MEASURED BY THE NEW IMPERIAL STANDARD WIRE-GAUGE.

Thickness by Number of the New Standard W. G.*	WEIGHT IN LBS.			Thickness by Number of the New Standard W. G.*	WEIGHT IN LBS.		
	White Metal.	Zinc.	Lead.		White Metal.	Zinc.	Lead.
7/0	19·50	18·50	29·50	11	4·52	4·30	6·85
6/0	18·01	17·17	27·38	12	4·06	3·85	6·14
5/0	16·85	16·00	25·49	13	3·59	3·41	5·43
4/0	15·60	14·80	23·60	14	3·12	2·96	4·73
3/0	14·51	13·77	21·95	15	2·81	2·67	4·25
2/0	13·58	12·88	20·54	16	2·50	2·37	3·78
0	12·64	12·00	19·11	17	2·19	2·08	3·31
1	11·70	11·10	17·70	18	1·88	1·78	2·84
2	10·77	10·22	16·29	19	1·56	1·48	2·37
3	9·83	9·33	14·87	20	1·41	1·34	2·13
4	9·05	8·59	13·69	21	1·25	1·19	1·89
5	8·27	7·85	12·51	22	1·09	1·04	1·66
6	7·49	7·11	11·33	23	·94	·89	1·42
7	6·87	6·52	10·39	24	·86	·82	1·30
8	6·24	5·93	9·45	25	·78	·74	1·18
9	5·62	5·33	8·50	26	·71	·67	1·07
10	5·00	4·74	7·56	27	·64	·61	·97

Table 120.—WEIGHT OF 12 INCHES SQUARE OF VARIOUS METALS.

Thickness.	Wrought Iron.	Cast Iron.	Steel.	Gun-Metal.	Brass.	Copper.	Tin.	Zinc.	Lead.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1/16	2·50	2·34	2·56	2·75	2·69	2·87	2·37	2·25	3·68
1/8	5·	4·69	5·12	5·5	5·38	5·75	4·75	4·5	7·37
3/16	7·50	7·03	7·68	8·25	8·07	8·62	7·12	6·75	11·05
1/4	10·	9·38	10·25	11·	10·75	11·5	9·5	9·	14·75
5/16	12·5	11·72	12·81	13·75	13·45	14·37	11·87	11·25	18·42
3/8	15·	14·06	15·36	16·50	16·14	17·24	14·24	13·50	22·10
7/16	17·5	16·41	17·93	19·25	18·82	20·12	16·17	15·75	25·80
1/2	20·	18·75	20·5	22·	21·5	23·	19·	18·	29·5
9/16	22·5	21·10	23·06	24·75	24·20	25·87	21·37	20·25	33·17
5/8	25·	23·44	25·62	27·50	26·90	28·74	23·74	22·50	36·84
11/16	27·5	25·79	28·18	30·25	29·58	31·62	26·12	24·75	40·54
3/4	30·	28·12	30·72	33·00	32·28	34·48	28·48	27·	44·20
13/16	32·5	30·48	33·28	35·75	34·95	37·37	30·87	29·25	47·92
7/8	35·	32·82	35·86	38·50	37·64	40·24	32·34	31·5	51·6
15/16	37·5	35·16	38·43	41·25	40·32	43·12	35·61	33·75	55·36
1	40·	37·5	41·	44·	43·	46·	38·	36·	59·
1 1/16	42·5	39·84	43·56	46·75	46·69	48·87	40·37	38·25	62·68
1 1/8	45·	42·19	46·12	49·50	48·38	51·75	42·75	40·5	66·37
1 3/16	47·5	44·53	48·68	52·25	51·07	54·62	45·12	42·75	70·05
1 1/4	50·	46·88	51·25	55·	53·80	57·48	47·48	45·	73·75
1 5/16	52·5	49·22	53·81	57·75	56·45	60·37	49·87	47·25	77·42
1 3/8	55·	51·56	56·36	60·50	59·14	63·24	52·24	49·50	81·10
1 7/16	57·5	53·91	58·93	63·25	61·82	66·12	54·17	51·75	84·80
1 1/2	60·	56·24	61·5	66·	64·56	68·96	56·96	54·	88·40
1 5/8	65·	60·94	66·62	71·50	69·90	74·74	61·74	58·50	95·84
1 3/4	70·	65·64	71·28	77·	75·28	80·48	64·34	63·	102·12
1 7/8	75·	70·32	76·86	82·5	80·64	86·24	71·22	67·5	110·72
2	80·	75·00	82·	88·	86·	92·	76·	72·	118·
2 1/8	85·	79·68	87·12	93·5	93·38	97·74	80·74	77·5	125·36
2 1/4	90·	84·38	92·25	99·	96·76	103·50	85·50	81·	132·74
2 3/8	95·	89·06	97·36	104·5	102·14	109·24	90·24	85·5	140·10
2 1/2	100·	93·76	102·5	110·	107·60	114·96	94·96	90·	147·5
2 5/8	105·	98·44	107·62	115·5	112·90	120·74	99·74	95·5	154·84
2 3/4	110·	103·12	112·72	121·	118·28	126·48	104·48	100·	162·20
2 7/8	115·	107·82	117·86	126·5	123·64	132·24	108·34	103·5	169·60
3	120·	112·50	123·00	132·	129·	138·	114·	108·	177·

Hoops.—To find the length of bar required to make a circular hoop.—*Rule:* Add the thickness of the bar to the inside diameter of the hoop, and multiply the result by 3 1/7. For angle-iron hoops, with the flange on the outside.—*Rule:* Add twice the thickness of the root to the inside diameter of the hoop, and multiply the result by 3 1/7. For angle-iron hoops with the flange inside the hoop.—*Rule:* Deduct twice the thickness of the root from the outside diameter, and multiply by 3 1/7.

Table 121.—Iron Wire.

The following Table, issued by the Iron and Steel Wire Manufacturers' Association, gives the sizes, weights, lengths, and breaking strains of iron wire, according to the New Imperial Standard Wire-gauge.

Size on Wire-Gauge.	Diameter.		Sectional Area in Square Inches.	Weight of		Length of Cwt.	Breaking Strain.		Size on Wire-Gauge.
	Inch.	Millimetres.		100 Yards.	One Mile.		Annealed.	Bright.	
				lb.	lb.	yds.	lb.	lb.	
7/0	·500	12·7	·1963	193·4	3404	58	10470	15700	7/0
6/0	·464	11·8	·1691	166·5	2930	67	9017	13525	6/0
5/0	·432	11·	·1466	144·4	2541	78	7814	11725	5/0
4/0	·400	10·2	·1257	123·8	2179	91	6702	10052	4/0
3/0	·372	9·4	·1087	107·1	1885	105	5796	8694	3/0
2/0	·348	8·8	·0951	93·7	1649	120	5072	7608	2/0
1/0	·324	8·2	·0824	81·2	1429	138	4397	6595	1/0
1	·300	7·6	·0707	69·6	1225	161	3770	5655	1
2	·276	7·	·0598	58·9	1037	190	3190	4785	2
3	·252	6·4	·0499	49·1	864	228	2660	3990	3
4	·232	5·9	·0423	41·6	732	269	2254	3381	4
5	·212	5·4	·0353	34·8	612	322	1883	2824	5
6	·192	4·9	·0290	28·5	502	393	1544	2316	6
7	·176	4·5	0243	24·	422	467	1298	1946	7
8	·160	4·1	·0201	19·8	348	566	1072	1608	8
9	·144	3·7	·0163	16·	282	700	869	1303	9
10	·128	3·3	·0129	12·7	223	882	687	1030	10
11	·116	3·	·0106	10·4	183	1077	564	845	11
12	·104	2·6	·0085	8·4	148	1333	454	680	12
13	·092	2·3	·0066	6·5	114	1723	355	532	13
14	·080	2·	·0050	5·	88	2240	268	402	14
15	·072	1·8	·0041	4·	70	2800	218	326	15
16	·064	1·6	·0032	3·2	56	3500	172	257	16
17	·056	1·4	·0025	2·4	42	4667	131	197	17
18	048	1·2	·0018	1·8	32	6222	97	145	18
19	·040	1·	·0013	1·2	21	9333	67	100	19
20	·036	0·9	·0010	1·	18	11200	55	82	20

Table 122.—Galvanised Wire.

New Standard W. G. Thickness.	Length in Yards per lb.	New Standard W. G. Thickness.	Length in Yards per lb.
	yards.		yards.
3	2	13	15½
6	3½	14	20
8	5	16	31
10	7½	18	51
12	12	20	100

Table 123.—WEIGHT OF 1 FOOT IN LENGTH OF ANGLE AND TEE-IRON.

Breadth of Iron.	THICKNESS OF THE MIDDLE OF EACH WEB OR FLANGE.									
	¼ inch.	5/16 inch.	⅜ inch.	7/16 inch.	½ inch.	9/16 inch	⅝ inch.	¾ inch.	⅞ inch.	1 inch.
Inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1 × 1	1·44	1·74								
1¼ × 1¼	1·86	2·25	2·95							
1½ × 1½	2·30	2·81	3·30	3·76						
1¾ × 1¾	2·73	3·34	3·93	4·50	5·05					
2 × 2	3·15	3·86	4·55	5·23	5·85	6·48				
2¼ × 2¼	3·56	4·38	5·19	5·95	6·70	7·40	8·12			
2½ × 2½	3·98	4·90	5·81	6·68	7·54	8·35	9·16			
2¾ × 2¾	4·40	5·43	6·44	7·42	8·38	9·30	10·21	11·95		
3 × 3	4·82	5·95	7·07	8·15	9·21	10·25	11·26	13·25		
3¼ × 3¼	5·24	6·48	7·70	8·90	10·06	11·20	12·31	14·50		
3½ × 3½	5·66	7·00	8·33	9·63	10·90	12·15	13·36	15·76		
3¾ × 3¾	6·08	7·53	8·96	10·36	11·75	13·08	14·40	17·06		
4 × 4	6·50	8·06	9·60	11·10	12·56	14·02	15·45	18·30		
4¼ × 4¼	6·92	8·58	10·22	11·83	13·41	14·96	16·50	19·55		
4½ × 4½	7·33	9·10	10·95	12·56	14·25	15·92	17·56	20·80		
4¾ × 4¾	7·75	9·64	11·48	13·31	15·10	16·85	18·58	22·08		
5 × 5		10·15	12·12	14·04	15·92	17·80	19·63	23·33		
5½ × 5½		11·20	13·36	15·50	17·61	19·67	21·72	25·80	29·84	
6 × 6		12·25	14·63	16·98	19·28	21·60	23·84	28·30	32·64	36·85
6½ × 6½				18·47	20·96	23·46	25·93	30·80	35·52	40·20
7 × 7				19·92	22·65	25·33	28·00	33·30	38·45	43·52

Table 124.—STRENGTH OF LEAD PIPES.

Internal Diameter.	Weight per Lineal Yard.	Bursting Pressure in lbs. per Square Inch.	Safe Working Pressure in lbs. per Square Inch.
Inches.	lbs.		
½	7	1560	390
⅝	8	1340	335
¾	10	1040	260
1	14	900	225
1¼	18	800	200
1½	22	700	175
1¾	24	600	150
2	29	500	125

Table 125.—SOLDER REQUIRED FOR JOINTS.

½ inch pipe takes ¾ lb. solder.
¾ do. „ 1 do.
1 do. „ 1¼ do.
1¼ do. „ 1½ do.
1½ do. „ 1¾ do.
1¾ do. „ 2 do.
2 do. „ 2¼ do.

Table 126.—WEIGHT OF CAST-IRON BALLS IN LBS.

Diameter.	Weight.	Diameter.	Weight.	Diameter.	Weight.
Inches.	lbs.	Inches.	lbs.	Inches.	lbs.
½	·07	6	29·47	11½	207·4
1	·14	6½	37·46	12	235·7
1½	·46	7	46·80	13	299·7
2	1·09	7½	57·57	14	374·3
2½	2·13	8	69·80	15	460·3
3	3·68	8½	83·77	16	558·7
3½	5·85	9	99·44	17	670·1
4	8·73	9½	116·9	18	795·5
4½	12·43	10	136·4	19	935·6
5	17·05	10½	157·9	20	1091·2
5½	22·60	11	181·6	21	1268·7

Balls.—To find the weight of balls of other metals: multiply the weight of cast iron balls by 1·2 for gun metal; 1·15 for brass; 1·08 for steel; and by 1·05 for wrought-iron.

Wood Screws.—GAUGE NUMBER, AND DIAMETER IN DECIMAL PARTS OF AN INCH.

Screw Gauge No..	1	2	3	4	5	6	7	8
Diameter, Inch.	·066	·080	·094	·108	·122	·136	·150	·164
Screw Gauge No..	9	10	11	12	13	14	15	16
Diameter, Inch.	·178	·192	·206	·220	·234	·248	·262	·276

Table 127.—WEIGHT OF LEAD PIPES.

Inside Diameter.	Length in Feet.	Thickness in Inches.	Weight per Length.	Thickness in Inches.	Weight per Length.	Thickness in Inches.	Weight per Length.	Thickness in Inches.	Weight per Length.
Inches.			lbs.		lbs.		lbs.		
½	15	3/32	15	1/8 f	18	1/8 f	22	5/32 b	25
⅝	15	1/8 b	18	1/8	22	1/8 f	27	5/32	30
¾	15	1/8 b	24	5/32	28	3/16	32	7/32	36
1	15	1/8	28	1/8 f	36	5/32	42	3/16	48
1¼	12	1/8 f	36	5/32	42	3/16	52	7/32	63
1½	12	1/8 f	42	5/32 f	48	3/16	56	1/8 b	72
1¾	12	3/16	70	1/4 b	84	1/4	96		
2	12	7/32	84	1/4 f	96	9/32	112		
2½	10	7/32 b	84	1/4	96	1/4 f	112		
3	10	1/4 f	120	9/32	150	5/16	188		
3½	10	1/4 b	135	1/4 b	150	5/16 b	184		
4	10	7/32	135	1/4 f	160	5/16 b	200		
4½	10	5/16	200	5/16 b	216	5/16	234		
5	10	5/16 b	234	5/16 b	254	11/32	280		
6	10	5/16	330						

NOTE.—F means full, and B bare thickness.

Table 128.—WEIGHT OF LEAD REQUIRED FOR THE JOINTS OF CAST-IRON SOCKET-PIPES.

Diameter of Pipe.	Weight of Lead.	Diameter of Pipe.	Weight of Lead.
Inches.	lbs.	Inches.	lbs.
2	2	10	12
2½	2½	11	13½
3	3	12	15
4	3¾	14	18
5	6	15	22
6	7	16	24
7	8	18	25
8	9	20	27
9	10½	24	38

Table 129.—WEIGHT OF ONE FOOT IN LENGTH OF ANGLE-STEEL AND TEE-STEEL.

Breadth of Steel.	THICKNESS OF THE MIDDLE OF EACH WEB OR FLANGE.									
	¼ Inch	5/16 Inch.	⅜ Inch.	7/16 Inch.	½ Inch.	9/16 Inch.	⅝ Inch.	¾ Inch.	⅞ Inch.	1 In.
Inches.	lbs									
1 × 1	1·47	1·78								
1¼ × 1¼	1·90	2·30	3·02							
1½ × 1½	2·35	2·87	3·37	3·84						
1¾ × 1¾	2·79	3·41	4·01	4·60	5·16					
2 × 2	4·22	3·94	4·65	5·34	5·98	6·6				
2¼ × 2¼	3·64	4·48	5·30	6·07	6·84	7·6	8·3			
2½ × 2½	4·07	4·50	5·94	6·82	7·70	8·5	9·4			
2¾ × 2¾	4·50	5·55	6·58	7·58	8·56	9·5	10·5	12·2		
3 × 3	4·93	6·08	7·22	8·33	9·41	10·5	11·5	13·5		
3¼ × 3¼	5·35	6·62	7 87	9·10	10·27	11·5	12·6	14·8		
3½ × 3½	5·78	7·15	8·51	9·84	11·13	12·4	13·7	16·1		
3¾ × 3¾	6·21	7·69	9·15	10·58	12·00	13·4	14·7	17·5		
4 × 4	6·64	8·23	9·80	11·34	12·83	14·7	15 8	18·7		
4¼ × 4¼	7·07	8·76	10·44	12·08	13·70	15·3	16·9	20·0		
4½ × 4½	7·49	9·30	11·18	12·83	14·55	16·3	18·0	21·3		
4¾ × 4¾	7·92	9·84	11·73	13·60	15·42	17·3	19·0	22·6		
5 × 5		10·36	12·37	14·34	16·26	18·2	20·1	23·8		
5½ × 5½		11·44	13·64	15·83	17·98	20·1	22·2	26·4	30·5	
6 × 6		12·51	14·94	17·34	19·79	22·2	24·4	28·9	33·4	38
6½ × 6½				18·86	21·40	24·0	26·5	31·5	36·3	41
7 × 7				20·34	23·13	25·9	28·6	37·4	39·3	45

11⅞ × 7/16 × 3 inches = 26 lbs.
9¼ × ⅜ × 3½ inches = 23 lbs.
7⅞ × 7/16 × 3⅛ inches = 20 lbs.

6 × ⅜ × 3 inches = 16½ lbs
4⅛ × 5/16 × 2½ inches = 10½ lbs.
2⅜ × ¼ × 1 3/16 inches = 4 lbs.

Table 130.—WEIGHT OF 12 INCHES IN LENGTH OF CAST-IRON CYLINDERS.

Internal Diameter.	THICKNESS IN INCHES.																
	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2
Inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$1\frac{1}{2}$	5·54	6·88	8·3	9·8	11·4	13·1	16·6	20·4	24·4	28·7	34·	42	45	50	56	62	69
2	7·07	8·72	10·5	12·3	14·2	16·	20·2	24·7	29·5	34·6	40·	46	52	58	65	72	79
$2\frac{1}{2}$	8·62	10·6	12·6	14·7	16·9	19·2	23·8	29·	34·4	40·	46·	53	59	66	74	81	89
3	10·2	12·4	14·8	17·2	19·6	22·2	27·6	33·3	39·3	45·6	52·	59	67	74	82	91	99
$3\frac{1}{2}$	11·7	14·3	16·9	19·6	22·4	25·3	31·3	37·5	44·2	51·	58·2	66	74	82	92	99	108
4	13·2	16·1	19·1	22·1	25·2	28·3	35·	41·8	49·	56·6	64·4	73	81	91	99	109	118
$4\frac{1}{2}$	14·8	18·	22·1	24·5	28·	31·5	38·7	46·2	54·	62·1	70·5	80	89	98	108	118	128
5	16·3	19·8	23·4	27·	30·6	34·5	42·2	50·5	58·9	67·6	76·6	86	96	106	117	127	138
$5\frac{1}{2}$	17·8	21·6	25·5	29·5	33·5	37·5	46·	54·7	63·8	73·1	82·7	94	104	115	125	136	148
6	19·4	23·5	27·7	32·	36·2	40·7	49·6	59·	68·6	78·6	90·	100	111	122	135	145	157
$6\frac{1}{2}$	21·	25·3	29·8	34·4	39·	43·7	53·4	63·4	73·6	84·1	95·	108	118	132	142	155	167
7	22·6	27·2	32·	36·8	41·8	46·8	57·1	67·6	78·5	89·7	102·	114	126	139	152	164	177
$7\frac{1}{2}$	24·2	29·	34·	39·2	44·5	50·	60·8	71·8	83·5	95·1	108·	121	133	146	159	173	187
8	25·5	30·8	36·2	41·7	47·2	51·	64·4	76·2	88·4	101·	114·	127	141	155	168	182	197
$8\frac{1}{2}$	27·2	32·7	38·3	44·2	50·	56·	68·	80·5	93·3	107·	120·	134	148	162	176	192	206
9	28·5	34·5	40·5	46·6	52·8	59·	71·7	84·8	98·	112·	126·	140	155	171	186	201	216
$9\frac{1}{2}$	30·2	36·4	42·6	49·	55·6	62·	75·5	89·	103·	118·	132·	147	162	178	194	210	226
10	31·6	38·2	44·7	51·5	58·3	65·	79·2	93·4	108·	123·	138·	154	170	186	202	219	236
$10\frac{1}{2}$	33·2	40·	47·	54·	61·	68·2	82·8	97·6	113·	129·	144·	162	177	195	212	228	246
11	34·7	41·9	49·	56·4	63·9	71·1	86·5	102·	118·	134·	151·	168	185	202	220	237	256
$11\frac{1}{2}$	36·2	43·7	51·3	58·9	66·6	74·5	90·1	107·	123·	140·	157·	175	192	210	228	242	266
12	38·	45·6	53·3	61·4	69·4	77·5	93·8	111·	128·	145·	163·	180	200	217	237	256	275
13	40·8	49·2	57·6	66·3	74·8	83·6	102·	120·	138·	156·	175·	194	215	233	252	265	295

Table 130 *continued.*—WEIGHT OF TWELVE INCHES IN LENGTH OF CAST-IRON CYLINDERS.

Internal Diameter.	THICKNESS IN INCHES.																
	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2
Inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
14	44·	52·9	62·	71·2	80·4	90·	109	128	148	168	187	207	229	245	272	295	314
15	47·1	56·	66·2	76·	85·9	91·	116	137	157	178	200	219	244	265	289	312	334
16	50·2	60·3	70·	81·	91·5	102·	124	145	167	190	212	234	259	282	305	332	353
17	53·5	64·	74·8	85·9	97·	108·	131	154	177	201	224	248	274	298	323	351	373
18	56·5	67·7	79·2	90·8	103·	115·	139	163	187	212	236	262	288	314	340	368	393
19	...	71·	84·	95·7	108·	121·	146	170	197	222	249	275	303	330	357	386	413
20	...	75·1	88·	100·4	114·	127·	153	180	206	232	261	290	318	345	374	405	432
21	...	79·	92·1	105·4	120·	133·	161	189	216	242	273	303	333	360	392	423	451
22	...	82·1	97·2	110·2	126·	139·	168	197	226	255	285	315	348	377	409	442	471
23	...	87·	101·	115·2	132·	145·	176	205	236	267	304	330	362	394	426	460	491
24	...	90·1	105·	121·	137·	152·	183	214	245	277	310	343	376	410	443	498	510
26	...	97·3	116·	130·	148·	164·	198	231	265	300	334	370	406	442	477	516	550
28	...	105·	123·	140·	159·	176·	213	249	285	321	359	397	436	474	512	553	590
30	...	112·	133·	150·	170·	188·	228	265	304	344	383	423	466	505	547	591	628
33	...	125·	144·	164·	187·	203·	249	289	334	374	420	463	510	553	598	642	687
36	...	135·	167·	179·	203·	221·	272	315	363	420	457	505	553	600	649	700	745
42	...	156·	182·	208·	237·	257·	315	366	422	476	530	585	642	696	753	813	863
48	...	178·	207·	238·	270·	295·	360	417	481	553	604	668	730	792	855	922	982
54	...	...	...	268·	304·	331·	404	468	540	610	678	749	818	888	958	1036	1098
60	...	...	...	297·	337·	367·	448	519	598	675	751	830	907	983	1062	1147	1217
66	...	...	...	326·	370·	403·	492	570	657	742	824	952	995	1083	1166	1260	1334
72	...	...	...	356·	404·	440·	536	622	716	807	898	995	1084	1188	1270	1371	1452

Table 131.—WEIGHT OF HALF A CIRCLE OF CAST-IRON—DEPTH = HALF THE DIAMETER.

Thickness in Inches.	INTERNAL DIAMETER IN INCHES.											
	36	39	42	45	48	54	60	66	72	78	84	96
	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.
½	2·5	2·96	3·42	3·8	4·4	5·57	6·84	8·26	9·8	11·5	13·3	17·3
¾	3·8	4·3	5·23	6·	6·8	8·35	10·45	12·6	14·9	17·5	20·2	26·2
1	5·3	6·2	7·12	8·14	9·2	11·5	14·15	17·	20·15	23·5	27·2	35·3
1¼	6·8	7·9	9·	10·3	11·7	14·7	17·9	21·5	25·5	28·8	34·3	44·5
1½	8·4	9·7	11·1	12·7	14·3	17·9	21·9	26·2	32·	36·2	41·7	54·
1¾	10·	11·6	13·3	15·1	17·	21·2	25·9	31·	36·6	40·7	49·2	63·7
2	11·7	13·6	15·5	17·6	19·9	24·7	30·1	36·	42·4	49·4	56·9	73·5

Table 132.—WEIGHT OF SMALL CAST-IRON SPUR WHEELS, OR CHANGE-WHEELS.

Pitch per inch in diameter	14	12	10	8	7	6	5	4	3½	3
Nearest circular pitch, inch	3/16	¼	5/16	⅜	7/16	½	⅝	¾	⅞	1
Width of face in inches .	11/16	⅞	1	1¼	1⅜	1½	1⅝	1¾	2	2¼
Number of teeth.	Weight of each Wheel in lbs.									
20			1	2	2½	3½	4	8	12	14
25		½	1¼	2½	3	4	6	10	15	21
30	½	¾	1¾	3	4½	5	7	12	19	27
35	¾	1	2	3½	5	6	9	14	22	32
40	1	1¼	3½	4¼	6	7	10	16	25	36
45	1¼	1½	4	4¾	6½	8	12	18	28	41
50	1½	1¾	4½	5½	7	9	14	20	31	46
55	1¾	2	5¼	6	8	10	16	24	34	50
60	2	2¼	6	6½	9	11	18	28	38	55
65	2¼	2½	6½	7	10½	12½	21	32	42	60
70	2½	2¾	7	7½	13	15	24	36	46	66
75	2¾	3	7½	8	15	17	27	40	51	71
80	3	3¼	8	9	16	18	30	45	56	76
85	3¼	3½	8½	10	17	19	32	50	62	81
90	3½	4	9½	11	18	20	35	55	67	84
95	4	4½	10	12	19	21	38	60	73	89
100	4½	5	11	13	20	22	42	65	78	92
105	5	5½	12	14	21	23	48	70	83	96
110	5½	6	13	15	22	24	53	75	88	100
115	6	6½	14	16	23	25	60	81	93	105
120	6½	7	15	17	24	26	66	86	98	112
125	7	7½	16	18	25	27	73	92	103	117
130	7½	8	17	19	26	28	80	97	108	122
135	8	8½	18	20½	27	29	86	102	114	127
140	8½	9	20	22	28	31	94	108	124	132
150	9½	10	22	25	32	36	100	114	134	140
160	11	12	25	30	37	44	107	122	145	153

Table 133.—WEIGHT OF CIRCULAR AND SQUARE CAST-IRON PLATES

Thickness. Inches.	Size of Plate, in Inches . .	4	5	8	10	12	15	18	21	24	30	36	42	48	54	60	66	72	84
⅜	Weight of round plate, in lbs.	1·23	2·75	4·9	7·7	11	17·2	25	34	45	69	100	135	175	223	276	334	397	540
	Weight of square plate, in lbs.	1·56	3·5	6·25	9·75	14·25	22·25	31·5	43·25	56·5	88	126	173	225	285	351	425	506	689
½	Weight of round plate, in lbs.	1·63	3·68	6·5	10·2	15	23	34	45	59	72	134	180	235	298	368	450	529	720
	Weight of square plate, in lbs.	2·08	4·68	8·3	13	18·7	29·2	42	58	75	117	168	230	300	380	468	567	674	918
⅝	Weight of round plate, in lbs.	2·04	4·6	8·16	13	18·4	29	42	57	74	116	168	228	296	368	456	544	661	900
	Weight of square plate, in lbs.	2·6	5·84	10·4	16·25	24	37	53	73	94	147	210	293	375	475	585	709	843	1148
¾	Weight of round plate, in lbs.	2·45	5·5	14·7	15·5	22	34·5	50·5	68	89	138	201	270	353	446	551	667	793	1080
	Weight of square plate, in lbs.	3·12	7·	12·5	19·5	28·5	44·5	63	86·5	113	176	252	345	450	570	702	850	1011	1377
⅞	Weight of round plate, in lbs.	2·85	6·44	11·44	18	26	40·2	58	79	103	161	232	316	412	520	645	785	926	1264
	Weight of square plate, in lbs.	3·64	7·73	14·5	22·7	33	52	73	102	132	205	294	358	525	665	819	1092	1180	1607
1	Weight of round plate, in lbs.	3·26	7·35	13	20·4	29·4	46	67	90	118	184	268	360	470	595	735	889	1058	1440
	Weight of square plate, in lbs.	4·16	9·3	16·6	26	37·5	58·5	84	115	150	234	336	460	601	759	936	1133	1348	1835
1⅛	Weight of round plate, in lbs.	3·67	8·28	14·7	23	33·4	52	75	102	133	208	300	408	532	666	832	1000	1200	1632
	Weight of square plate, in lbs.	4·68	10·5	18·7	29·25	42·7	68	95	131	169	264	378	473	675	850	1053	1276	1517	2066
1¼	Weight of round plate, in lbs.	4·08	9·2	16·3	26	37	58	84	114	148	232	336	456	592	736	912	1088	1322	1800
	Weight of square plate, in lbs.	5·2	11·6	20·8	32·5	48	74	106	146	188	294	420	586	750	950	1170	1418	1686	2296
1⅜	Weight of round plate, in lbs.	4·49	10·1	18	28	41	64	92	124	163	256	368	496	652	818	1024	1223	1472	1985
	Weight of square plate, in lbs.	5·72	12·8	22·8	35·7	52	81	116	159	207	322	462	588	826	1044	1287	1558	1854	2524
1½	Weight of round plate, in lbs.	4·9	11	19·6	31	44	69	101	135	177	276	402	540	705	893	1103	1334	1587	2160
	Weight of square plate, in lbs.	6·24	14	25	39	57	89	126	173	225	351	504	690	901	1139	1404	1700	2022	2753

Table 134.—Weight of 1 Foot in Length of Round and Square Cast-Brass Bars, Copper, Lead, and Zinc Bars; and also of 100 Feet in Length of Brass and Copper Wire.

Size of Bar, in Inches . .	½	⅝	¾	⅞	1	1⅛	1¼	1⅜	1½	1⅝	1$\frac{8}{4}$	1⅞	2	2¼	2½	2¾	3	3½	4
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Weight of round brass	·71	1·1	1·6	2·16	2·84	3·6	4·44	5·37	6·4	7·5	8·7	10·	11·4	15·	18·	22	26	35	46
Weight of round copper	·75	1·17	1·7	2·3	3·	3·8	4·68	5·66	6·7	7·9	9·2	10·5	12·	16·	19·	23	27	37	48
Weight of square brass	·91	1·42	2·	2·77	3·65	4·6	5·68	6·9	8·0	9·6	11·	12·8	15·	19·	23·	28	32	44	60
Weight of square copper	·96	1·5	2·16	2·9	3·84	4·9	6·	7·26	8·7	10·1	11·7	13·5	16·	20·	24·	29	35	47	63
Weight of round lead .	·95	1·48	2·14	2·86	3·8	4·9	6·	7·25	8·7	10·1	11·7	13·5	16·	20·	24·	29	35	47	63
Weight of round zinc .	·64	·95	1·36	1·83	2·5	3·	3·8	4·5	5·4	6·3	7·3	8·4	9·8	12·	15·2	18	22	30	40
Weight of square lead .	1·25	1·93	2·33	3·83	5·	6·3	7·7	9·3	11·1	13·1	15·3	17·5	20·	25·	31·	38	45	62	80
Weight of square zinc .	·8	1·21	1·8	2·4	3·1	4·	4·9	5·9	6·9	8·2	9·6	11·	13·	16·	20·	24	28	38	50
Wire, thickness by the New Standard W. G.	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Weight of 100 feet in length of brass wire, in lbs.	·44	·66	·88	1·17	1·47	1·83	2·38	3·08	3·82	4·66	5·88	7·27	8·8	10·46	12·8	15·3	18	22	26
Weight of 100 feet in length of copper wire, in lbs.	·47	·7	·93	1·22	1·55	1·93	2·5	3·24	4·02	4·9	6·18	7·64	9·3	11·0	13·5	16·1	19	24	28

Table 135.—WEIGHT AND GAUGES OF SHEET ZINC.

Thickness by Zinc Gauge.	Nearest Thickness by the New Standard Wire-Gauge.	Approximate Weight per Square Foot in Ounces.	APPROXIMATE WEIGHT PER SHEET.							
			ft. ft. in. 7 × 2 8		ft. ft. 7 × 3		ft. ft. in. 8 × 2 8		ft. ft. 8 × 3	
			lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.
4	...	5	5	13	6	9	6	11	7	8
5	...	6	7	0	7	14	8	0	9	0
6	...	7	8	3	9	3	9	6	10	8
7	...	8	9	5	10	8	10	10	12	0
8	...	9	10	8	11	13	12	0	13	12
9	25	11	12	13	14	7	14	11	16	8
10	24	13	15	3	17	1	17	5	19	8
11	22	15	17	8	19	11	20	0	22	8
12	21	17	19	13	22	5	22	11	25	8
13	20	19½	22	12	25	10	26	0	29	4
14	19	22	25	11	28	14	29	5	33	0
15	...	24	28	0	31	8	32	0	36	0
16	18	26	30	5	34	2	34	11	39	0
17	18	30	35	0	39	6	40	0	45	0

Table 136.—SIZES AND WEIGHTS OF TIN PLATES.

Mark.	Size.	Sheets per Box.	Weight.		
	in. in.		cwt.	qr.	lb.
IC	14×10	225	1	0	0
IX	14×10	225	1	1	0
IXX	14×10	225	1	1	21
IXXX	14×10	225	1	2	14
IC	14×20	112	1	0	0
IX	14×20	112	1	1	0
IXX	14×20	112	1	1	21
IXXX	14×20	112	1	2	14
SDC	15×11	200	1	1	27
SDX	15×11	200	1	2	20
SDXX	15×11	200	1	3	13
DC	17×12½	100	0	3	14
DX	17×12½	100	1	0	14
DXX	17×12½	100	1	1	7

Table 137.—SIZES OF BORE OF GUNS.

Number of Gun-Gauge.	Diameter of Bore, in Decimals of an Inch.	Number of Gun-Gauge.	Diameter of Bore, in Decimals of an Inch.
4 varies from	1·052 to 1·000	14 varies from	·693 to ·680
6 „	·919 „ ·900	16 „	·662 „ .650
8 „	·835 „ ·820	20 „	·615 „ ·610
10 „	·775 „ ·760	24 „	·579 „ ·577
12 „	·729 „ ·750	28 „	·550 „ ·548

Table 138.—THICKNESS AND WEIGHT OF A SUPERFICIAL FOOT OF WINDOW-GLASS.

Number	12	13	15	16	17	19	21	24	26	32	36	42
Thickness in inches	·059	·063	·071	·077	·083	·091	·1	·111	·125	·154	·167	·2
Weight in ounces	12	13	15	16	17	19	21	24	26	32	36	42

Table 139.—WEIGHT AND THICKNESS OF SHEET-LEAD.

Thickness in inches	·018	·035	·052	·068	·086	·101	·12	·136	·154	·17	·187	·205
Weight in lbs. per superficial foot	1	2	3	4	5	6	7	8	9	10	11	12

Table 140.—SIZE AND WEIGHT OF IRON RIVETS AND COPPER RIVETS.

Number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Diameter in inches	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	1
Length in inches	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{5}{16}$	1	$1\frac{3}{16}$	$1\frac{5}{16}$	$1\frac{7}{16}$	$1\frac{9}{16}$	$1\frac{3}{4}$	$1\frac{13}{16}$	$2\frac{1}{16}$	$2\frac{3}{8}$
Number per lb. of iron rivets	330	128	114	65	59	40	38	24	16	11·3	8·2	6·2	4·8	3·8	3	2
Number per lb. of copper rivets	240	100	98	57	51	36	33	21	14	10	7·2	5·4	4·2	3·3	2·6	1·7

Table 141.—WEIGHT AND GAUGES OF GALVANIZED SHEET-IRON.

B. G. sheet-gauge, number	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	14
Weight per square foot, ounces	8	9	10	$11\frac{1}{2}$	13	$14\frac{1}{2}$	16	18	20	$22\frac{1}{2}$	$25\frac{1}{2}$	$28\frac{1}{2}$	32	36	40	$44\frac{1}{2}$

Table 142.—Birmingham Wire-Gauge; Stub's Wire-Gauge; American Wire-Gauge; and French Wire-Gauge.

Number of Wire-Gauge	Size of each Number in Decimal Parts of an Inch.			
	Birmingham Wire-Gauge.	Stub's Wire-Gauge.	Brown & Sharp's American Wire-Gauge.	Limoges French Wire-Gauge
	Inch.	Inch.	Inch.	Inch.
0000	·454	...	·46000	...
000	·425	...	·40964	...
00	·380	...	·36480	...
0	·340	...	·32495	·0154
1	·300	·227	·28930	·0177
2	·284	·219	·25763	·0221
3	·259	·212	·22942	·0264
4	·238	·207	·20431	0311
5	·220	·204	·18194	·0354
6	·203	·201	16202	·0398
7	·180	·199	14428	·0441
8	·165	·197	·12849	·0488
9	·148	·194	·11443	·0532
10	·134	·191	·10189	·0575
11	·120	·188	·09074	·0661
12	·109	·185	·08081	·0706
13	·095	·182	·07196	·0752
14	·083	·180	·06408	·0795
15	·072	·178	·05707	·0843
16	·065	·175	·05082	·0886
17	·058	·172	·04525	·1120
18	·049	·168	·04030	·1340
19	·042	·164	·03589	·1560
20	·035	·161	·03196	·1770
21	·032	·157	·02846	·2010
22	·028	·155	·02535	·2220
23	·025	·153	·02257	·2440
24	·022	·151	·02010	·2681
25	·020	·148	·01790	·2850
26	·018	·146	·01594	
27	·016	·143	·01419	
28	·014	·139	·01264	
29	·013	·134	·01126	
30	·012	·127	·01002	
31	·010	·120	·00893	
32	·009	·115	·00795	
33	·008	·112	·00708	
34	·007	·110	·00630	
35	·005	·108	·00561	
36	·004	·106	·00500	
37		·103	·00445	
38		·101	·00396	
39		·099	·00353	
40		·097	·00314	

The Standard wire gauge (page 313) is the only legal wire gauge for the United Kingdom.

Table 143.—WEIGHT OF A SQUARE FOOT OF COPPER, BRASS, AND WHITE METAL; THE THICKNESS BEING MEASURED BY THE BIRMINGHAM WIRE-GAUGE.

Thickness by Number of B. W. G.	WEIGHT IN POUNDS.			Thickness by Number of B. W. G.	WEIGHT IN POUNDS.		
	Copper.	Brass.	White-Metal.		Copper	Brass.	White-Metal.
	lbs.	lbs.	lbs.		lbs.	lbs.	lbs.
1 or $\frac{5}{16}$ inch	14·75	13·94	11·64	16 or $\frac{1}{16}$ inch	3·01	2·95	2·53
2	13·91	13·20	11·02	17	2·52	2·40	2·25
3 or $\frac{1}{4}$ inch	12·75	12·11	10·00	18	2·16	2·04	1·91
4	11·60	11·01	9·23	19	1·97	1·87	1·63
5	10·10	9·62	8·53	20	1·78	1·69	1·36
6	9·41	8·93	7·87	21	1·62	1·54	1·25
7 or $\frac{3}{16}$ inch	8·70	8·25	6·98	22 or $\frac{1}{32}$ inch	1·45	1·37	1·10
8	7·91	7·54	6·41	23	1·30	1·23	·97
9	7·20	6·86	5·75	24	1·16	1·10	·86
10	6·51	6·18	5·20	25	1·04	·98	·77
11 or $\frac{1}{8}$ inch	5·80	5·51	4·66	26	·92	·88	·70
12	5·08	4·81	4·23	27	·83	·79	·62
13	4·34	4·12	3·75	28 or $\frac{1}{64}$ inch	·74	·70	·55
14	4·00	3·75	3·22	29	·64	·61	·51
15	3·27	3·15	2·80	30	·58	·55	·47

Table 144.—WEIGHT OF A SQUARE FOOT OF WROUGHT-IRON, MILD-STEEL, AND LEAD; THE THICKNESS BEING MEASURED BY THE BIRMINGHAM WIRE-GAUGE.

Thickness by Number of B. W. G.	WEIGHT IN POUNDS.			Thickness by Number of B. W. G.	WEIGHT IN POUNDS.		
	Wrought Iron.	Mild Steel.	Lead.		Wrought Iron.	Mild Steel.	Lead.
	lbs.	lbs	lbs.		lbs.	lbs.	lbs.
1 or $\frac{5}{16}$ inch	12·00	12·25	17·70	16 or $\frac{1}{16}$ inch	2·60	2·65	3·84
2	11·36	11·59	16·75	17	2·32	2·37	3·43
3 or $\frac{1}{4}$ inch	10·36	10·57	15·28	18	1·96	2·01	2·89
4	9·52	9·71	14·04	19	1·68	1·71	2·48
5	8·81	8·98	12·98	20	1·40	1·43	2·07
6	8·12	8·28	11·97	21	1·28	1·31	1·89
7 or $\frac{3}{16}$ inch	7·20	7·35	10·62	22 or $\frac{1}{32}$ inch	1·12	1·14	1·65
8	6·61	6·73	9·73	23	1·00	1·02	1·48
9	5·92	6·05	8·74	24	·88	·90	1·29
10	5·36	5·47	7·91	25	·80	·83	1·18
11 or $\frac{1}{8}$ inch	4·80	4·90	6·58	26	·72	·74	1·06
12	4·36	4·45	6·44	27	·64	·65	·95
13	3·80	3·88	5·61	28 or $\frac{1}{64}$ inch	·56	·57	·83
14	3·32	3·39	4·64	29	·52	·53	·77
15	2·88	2·94	4·25	30	·48	·49	·71

Welded Joints.—The strength of a welded joint is very uncertain, because it depends upon the quality of the fuel used in heating it, the shape and area of the joint, the heat at which the iron is worked, the weight of the hammer used, and the quality of the workmanship. The strength of a butt-welded joint is frequently only 75 per cent., a lap-welded joint 80 per cent., and a V-welded joint 85 per cent. of that of the solid or unwelded bar.

Naval-Brass.—Naval-brass offers considerable resistance to corrosion. It consists of copper 62 per cent., zinc 37 per cent., and tin 1 per cent. Its specific gravity is 8·41; and the weight of a cubic foot is 525 lbs. The tensile strength of naval-brass when annealed is 21 tons per square inch.

Table 145.—WEIGHT OF ONE SQUARE FOOT OF PLATES OF NAVAL-BRASS OF VARIOUS THICKNESS.

THICKNESS.		Weight of One Square Foot in Pounds.	THICKNESS.		Weight of One Square Foot in Pounds.
Imperial Standard Wire-Gauge.	Equivalents in Parts of an Inch.		Imperial Standard Wire-Gauge.	Equivalents in Parts of an Inch.	
	$\frac{1}{16}$	2·734	6	·192	8·400
	$\frac{1}{8}$	5·468	7	·176	7·700
	$\frac{3}{16}$	8·202	8	·160	7·000
	$\frac{1}{4}$	10·936	9	·144	6·300
	$\frac{5}{16}$	13·670	10	·128	5·600
	$\frac{3}{8}$	16·404	11	·116	5·075
	$\frac{7}{16}$	19·138	12	·104	4·550
	$\frac{1}{2}$	21·872	13	·092	4·025
	$\frac{9}{16}$	24·606	14	·080	3·500
	$\frac{5}{8}$	27·343	15	·072	3·150
	$\frac{11}{16}$	30·074	16	·064	2·800
	$\frac{3}{4}$	32·808	17	·056	2·450
	$\frac{13}{16}$	35·542	18	·048	2·100
	$\frac{7}{8}$	38·276	19	·040	1·750
	$\frac{15}{16}$	41·010	20	·036	1·575
	1	43·750	21	·032	1·400
7/0	·500	21·875	22	·028	1·225
6/0	·464	20·300	23	·024	1·050
5/0	·432	18·900	24	·022	·962
4/0	·400	17·500	25	·020	·875
3/0	·372	16·275	26	·018	·787
2/0	·348	15·225	27	·0164	·717
0	·324	14·175	28	·0148	·647
1	·300	13·125	29	·0136	·595
2	·276	12·075	30	·0124	·542
3	·252	11·025	31	·0116	·507
4	·232	10·150	32	·0108	·472
5	·212	9·275			

Table 146.—Weight of One Foot in Length of Round Bars of Naval-Brass.

Diameter of Bar in Inches.	Weight in Pounds.	Diameter of Bar in Inches	Weight in Pounds.	Diameter of Bar in Inches.	Weight in Pounds.
½	·7	2	11·45	4½	58·00
⅝	1·12	2⅛	12·86	4¾	64·86
¾	1·62	2¼	14·50	5	71·95
⅞	2·20	2⅜	16·14	5¼	79·14
1	2·88	2½	18·00	5½	87·20
1⅛	3·65	2¾	21·60	5¾	94·84
1¼	4·48	3	25·73	6	103·55
1⅜	5·42	3¼	29·65	6½	121·00
1½	6·41	3½	35·10	7	141·70
1⅝	7·55	3¾	40·35	8	183·12
1¾	8·78	4	45·82	9	232·17
1⅞	10·02	4¼	51·25	10	287·76

Muntz-Metal consists of copper 60 per cent., and zinc 40 per cent. When annealed, its tenacity is from 22 tons to 28 tons per square inch.

Table 147.—Weight of One Square Foot of Muntz Metal Plates rolled by Muntz's Metal Co., Limited.

Thickness.			Weight of One Square Foot in Pounds.	Thickness.			Weight of One Square Foot in Pounds.
Birmingham Wire Gauge.	Inch.	Millimetres.		Birmingham Wire Gauge.	Inch.	Millimetres.	
1	·300	7·62	14·000	16	·065	1·65	3·00
2	·284	7·21	13·000	17	·058	1·47	2·75
3	·259	6·58	12·000	18	·049	1·24	2·25
4	·238	6·04	11·000	19	·042	1·07	2·00
5	·220	5·59	10·125	20	·035	·89	1·75
6	·203	5·16	9·500	21	·032	·81	1·50
7	·180	4·57	8·500	22	·028	·71	1·375
8	·165	4·19	7·625	23	·025	·63	1·1875
9	·148	3·76	7·000	24	·022	·56	1·0000
10	·134	3·40	6·250	25	·020	·51	·8750
11	·120	3·05	5·500	26	·018	·46	·8125
12	·109	2·77	5·000	27	·016	·41	·71875
13	·095	2·41	4·500	28	·014	·36	·62500
14	·083	2·11	4·000	29	·013	·33	·5625
15	·072	1·83	3·500	30	·012	·31	·5000

Weight of various Bronzes.—In the following table is given the approximate weight of one square foot of various bronzes, the compositions of which are as follows :—

The manganese bronze in column A. of the table is composed of 53 per cent. of copper, 42 per cent. of zinc, 3¾ per cent. of manganese, and 1¼ per cent. of aluminium.

The manganese bronze in column B. is composed of 60 per cent. of copper, 37 per cent. of zinc, 1 per cent. of tin, 2 per cent. of iron, and ·05 per cent. of manganese.

The nickel-bronze in column C. is composed of 70 per cent. of copper, 20 per cent. of nickel, and 10 per cent. of zinc.

The ordinary bronze in column D. is composed of 90 per cent. of copper and 10 per cent. of tin.

The silicon-bronze in column E. is composed of 97 per cent. of copper and 3 per cent. of silicon.

Table 148.—APPROXIMATE WEIGHT OF ONE SQUARE FOOT OF CAST PLATES OF MANGANESE BRONZE, NICKEL-BRONZE, ORDINARY BRONZE, AND SILICON-BRONZE.

Thickness of Plate.	Approximate Weight of One Square Foot of Manganese Bronze. A.	Approximate Weight of One Square Foot of Manganese Bronze. B.	Approximate Weight of One Square Foot of Nickel-Bronze. C.	Approximate Weight of One Square Foot of Ordinary Bronze. D.	Approximate Weight of One Square Foot of Silicon-Bronze. E.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{16}$	2·6	2·7	2·75	2·8	2·9
$\frac{3}{32}$	3·9	4·1	4·13	4·2	4·4
$\frac{1}{8}$	5·2	5·4	5·50	5·6	5·8
$\frac{5}{32}$	6·5	6·8	6·88	7·0	7·3
$\frac{3}{16}$	7·8	8·1	8·25	8·4	8·7
$\frac{7}{32}$	9·1	9·5	9·63	9·8	10·2
$\frac{1}{4}$	10·4	10·8	11·00	11·2	11·6
$\frac{9}{32}$	11·7	12·2	12·38	12·6	13·1
$\frac{5}{16}$	13·0	13·5	13·75	14·0	14·5
$\frac{11}{32}$	14·3	14·9	15·13	15·4	16·0
$\frac{3}{8}$	15·6	16·2	16·50	16·8	17·4
$\frac{13}{32}$	16·9	17·6	17·88	18·2	18·9
$\frac{7}{16}$	18·2	18·9	19·25	19·6	20·3
$\frac{15}{32}$	19·5	20·3	20·63	21·0	21·8
$\frac{1}{2}$	20·8	21·6	22·00	22·4	23·2
$\frac{9}{16}$	23·4	24·3	24·75	25·2	26·1
$\frac{5}{8}$	25·0	27·0	27·50	28·0	29·0
$\frac{11}{16}$	28·6	29·7	30·25	30·8	31·9
$\frac{3}{4}$	31·2	32·4	33·00	33·6	34·8
$\frac{13}{16}$	33·8	35·1	35·75	36·4	37·7
$\frac{7}{8}$	36·4	37·8	38·50	39·2	40·6
$\frac{15}{16}$	39·0	40·5	41·25	42·0	43·5
1	41·6	43·2	44·00	44·8	46·4

Weight of various Antifriction Metals.—The white metal in column A. of the following table represents the average of several different compositions called Babbitt's metal.

The white metal in column B. is composed of 86 per cent. of tin, 9 per cent. of antimony, and 5 per cent. of copper.

The white metal in column C. is composed of 83 per cent. of tin, 9 per cent. of antimony, and 8 per cent. of copper.

The white metal in column D. is composed of 82 per cent. of tin, 14 per cent. of lead, and 4 per cent of copper.

The white metal in column E. is composed of 70 per cent. of tin, 9 per cent. of antimony, 17 per cent. of lead, and 4 per cent. of copper.

The white metal in column F. is composed of 76 per cent. of lead, 10 per cent. of antimony, and 14 per cent. of tin.

The white metal in column G. is composed of 80 per cent. of lead, 15 per cent. of antimony, 4½ per cent. of tin, and ½ per cent. of bismuth.

Table 149.—APPROXIMATE WEIGHT OF ONE SQUARE FOOT OF CAST PLATES OF ANTIFRICTION WHITE METAL OF VARIOUS COMPOSITION.

Thickness.	Approximate Weight of One Square Foot of White Metal. A.	Approximate Weight of One Square Foot of White Metal. B.	Approximate Weight of One Square Foot of White Metal. C.	Approximate Weight of One Square Foot of White Metal. D.	Approximate Weight of One Square Foot of White Metal. E.	Approximate Weight of One Square Foot of White Metal. F.	Approximate Weight of One Square Foot of White Metal. G.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1/16	2·4	2·46	2·56	2·72	2·76	3·38	3·4
1/8	2·8	4·92	5·12	5·44	5·52	6·76	6·8
3/16	7·2	7·38	7·68	8·16	8·28	10·14	10·2
1/4	9·8	9·84	10·24	10·88	11·04	13·52	13·6
5/16	12·2	12·30	12·80	13·60	13·80	16·90	17·0
3/8	14·6	14·76	15·36	16·32	16·56	20·28	20·4
7/16	17·0	17·22	17·92	19·04	19·32	23·66	23·8
1/2	19·4	19·68	20·48	21·76	22·08	27·04	27·2
9/16	21·8	22·14	23·04	24·48	24·84	30·42	30·6
5/8	24·0	24·60	25·60	27·20	27·60	33·80	34·0
11/16	26·4	27·06	28·16	29·92	30·36	37·18	37·4
3/4	28·8	29·52	30·72	32·64	33·12	40·56	40·8
13/16	31·2	32·98	33·28	35·36	35·88	43·94	44·2
7/8	33·6	34·44	35·84	38·08	38·64	47·32	47·6
15/16	36·0	36·90	38·40	40·80	41·40	50·70	51·0
1	38·4	39·36	40·96	43·52	44·16	54·08	54·4

Table 150.—WEIGHT OF ONE FOOT IN LENGTH OF SMALL BRASS TUBES.

Internal Diameter.	THICKNESS OF BRASS TUBE IN INCHES.							
	1/16	1/8	3/16	1/4	[illegible]	3/8	7/16	1/2
Inch.								
1/4	·23	·55	1·00	1·47	2·08	2·74	3·47	4·32
1/2	·43	·93	1·60	2·20	3·01	3·80	4·75	5·90
3/4	·63	1·30	2·15	2·91	3·85	4·90	6·07	7·40
1	·81	1·67	2·70	3·74	4·80	6·00	7·31	8·80

Weight of Plates of several kinds of Steel.—The steel in column A. of Table 151 contains 12 per cent. of manganese.

The nickel-steel in column B. contains 3 per cent. of nickel.

The nickel-steel in column C. contains 10 per cent. of nickel.

The nickel-steel in column D. contains 20 per cent. of nickel.

The compressed steel in column E. is ordinary mild carbon-steel, of average quality, compressed while fluid.

Table 151.—APPROXIMATE WEIGHT OF ONE SQUARE FOOT OF PLATES OF MANGANESE STEEL, NICKEL-STEEL AND COMPRESSED MILD STEEL.

Thickness of Plate.	Weight of One Square Foot of Manganese Steel. A.	Weight of One Square Foot of Nickel-Steel. B.	Weight of One Square Foot of Nickel-Steel. C.	Weight of One Square Foot of Nickel-Steel. D.	Weight of One Square Foot of Compressed Mild Steel. E.
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{16}$	2·54	2·56	2·58	2·6	2·8
$\frac{3}{32}$	3·81	3·84	3·87	3·9	4·2
$\frac{1}{8}$	5·08	5·12	5·16	5·2	5·6
$\frac{5}{32}$	6·35	6·40	6·45	6·5	7·0
$\frac{3}{16}$	7·62	7·68	7·74	7·8	8·4
$\frac{7}{32}$	8·89	8·96	9·03	9·1	9·8
$\frac{1}{4}$	10·16	10·24	10·32	10·4	11·2
$\frac{9}{32}$	11·43	11·52	11·61	11·7	12·6
$\frac{5}{16}$	12·70	12·80	12·90	13·0	14·0
$\frac{11}{32}$	13·97	14·08	14·19	14·3	15·4
$\frac{3}{8}$	15·24	15·36	15·48	15·6	16·8
$\frac{13}{32}$	16·51	16·64	16·77	16·9	18·2
$\frac{7}{16}$	17·78	17·92	18·06	18·2	19·6
$\frac{15}{32}$	19·05	19·20	19·35	19·5	20·8
$\frac{1}{2}$	20·32	20·48	20·64	20·8	22·4
$\frac{9}{16}$	22·86	23·04	23·22	23·4	25·2
$\frac{5}{8}$	25·40	25·60	25·80	26·0	28·0
$\frac{11}{16}$	27·94	28·16	28·38	28·6	30·8
$\frac{3}{4}$	30·48	30·72	30·96	31·2	33·6
$\frac{13}{16}$	33·02	33·28	33·54	33·8	36·4
$\frac{7}{8}$	35·56	35·84	36·12	36·4	39·2
$\frac{15}{16}$	38·10	38·40	38·70	39·0	42·0
1	40·64	40·96	41·28	41 6	44·8

Table 152.—WEIGHT OF ONE FOOT IN LENGTH OF SMALL COPPER TUBES.

Internal Diameter.	THICKNESS OF COPPER TUBE IN INCHES.							
	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{4}$	·24	·60	1·05	1·54	2·20	2·87	3·68	4·50
$\frac{1}{2}$	·45	·99	1·62	2·34	3·15	4·04	5·00	6·16
$\frac{3}{4}$	·65	1·37	2·18	3·05	4·10	5·17	6·34	7·65
1	·85	1·74	2·76	3·83	5·03	6·30	7·68	9·14

Aluminium is a remarkably light metal, its specific gravity, when cast in sand, being only one-third that of wrought iron. When the metal is properly treated, the colour of aluminium, of 98½ per cent. purity, is bright white, nearly like silver. It is strong, ductile, easily worked, and not liable to rust. It may be easily melted in crucibles, and its specific heat is very high. Annealed aluminium is so soft and ductile that it may be beaten and drawn into the finest leaves and threads, like silver.

Castings of aluminium are greatly improved in rigidity and strength by forging. The tensile strength of aluminium per square inch is generally from 5 to 7 tons when cast and not annealed, with elongation 3 per cent. from 11 to 17 tons when hard wrought and not annealed, with elongation 4 per cent.; and from 5 to 6½ per cent. when wrought and annealed, with elongation from 18 to 26 per cent.

Table 153.—WEIGHT OF ONE SQUARE FOOT OF SHEET-ALUMINIUM.
(BRITISH ALUMINIUM CO., LIMITED.)

THICKNESS.		Weight of One Square Foot in Pounds	THICKNESS.		Weight of One Square Foot in Pounds.	THICKNESS.		Weight of One Square Foot in Pounds.
Imperial Standard Wire-Gauge.	Inch.		Imperial Standard Wire-Gauge.	Inch.		Imperial Standard Wire-Gauge.	Inch.	
	1·000	13·82		·216	2·98	24	·022	·304
	·937	12·95	5	·212	2·93	25	·020	·276
	·875	12·09		·200	2·76	26	·018	·248
	·812	11·22	6	·192	2·65	27	·0164	·226
	·750	10·36		·187	2·58	28	·0148	·204
	·687	9·49		·182	2·51	29	·0136	·188
	·625	8·64	7	·176	2·43	30	·0124	·172
	·562	7·76		·166	2·29	31	·0116	·160
	·500	6·91	8	·160	2·21	32	·0108	·149
	·464	6·41		·150	2·07	33	·0105	·145
	·437	6·04	9	·144	1·99	34	·0092	·127
	·432	5·97		·136	1·88	35	·0084	·116
	·400	5·55	10	·128	1·76	36	·0076	·105
	·375	5·18		·125	1·72	37	·0068	·094
	·372	5·14	11	·116	1·60	38	·0060	·083
	·348	4·81	12	·104	1·43	39	·0052	·071
	·324	4·47	13	·092	1·27	40	·0048	·0663
	·312	4·31	14	·080	1·10	41	·0044	·0608
1	·300	4·14	15	·072	·99	42	·0040	·0552
	·289	3·99	16	·064	·88	43	·0036	·0497
2	·276	3·81	17	·056	·77	44	·0032	·0442
	·278	3·84	18	·048	·66	45	·0028	·0387
	·270	3·72	19	·040	·555	46	·0024	·0331
3	·252	3·48	20	·036	·497	47	·0020	·0276
	·250	3·45	21	·032	·442	48	·0016	·0221
	·238	3·29	22	·028	·387	49	·0012	·0165
4	·232	3·20	23	·024	·332	50	·0010	·0138

The weight per square foot of aluminium, 1 inch thick, of 98½ per cent purity, is 13⅓ pounds when cast, and 14 pounds when hard wrought.

The addition of a very small quantity of aluminium to cast iron, steel, and bronze, greatly improves their homogeneity, and conduces to the production of sound and close-grained castings.

Table 154.—WEIGHT IN POUNDS OF ONE FOOT IN LENGTH OF ALUMINIUM TUBES. (BRITISH ALUMINIUM CO., LIMITED.)

Thickness. Birmingham Wire Gauge.	1	3	5	8	11	15	20	24
Thickness. Inch.	·300	·259	·220	·165	·120	·072	·035	·022
External Diameter in Inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
¼	...	...	...	...	...	·05	·03	·02
⅜	...	...	...	...	·12	·08	·04	·03
½	...	...	...	·22	·18	·12	·06	·04
⅝	...	...	...	·30	·23	·15	·08	·05
¾	...	...	...	·37	·29	·19	·09	·06
⅞	...	·61	·56	·45	·35	·22	·11	·07
1	·80	·74	·66	·53	·41	·26	·13	·08
1⅛	·94	·86	·76	·61	·46	·29	·15	·09
1¼	1·09	·98	·87	·69	·52	·33	·16	·10
1⅜	1·23	1·11	·97	·77	·58	·36	·18	·11
1½	1·36	1·23	1·08	·85	·64	·39	·19	·12
1⅝	1·52	1·36	1·18	·93	·69	·43	·21	·13
1¾	1·66	1·48	1·29	1·01	·75	·47	·23	·14
1⅞	1·81	1·60	1·39	1·09	·81	·50	·24	·15
2	1·94	1·73	1·50	1·17	·87	·53	·26	·16
2¼	2·23	1·97	1·71	1·32	·98	·60	·30	·18
2½	2·52	2·22	1·92	1·48	1·10	·69	·33	·21
2¾	2·80	2·47	2·12	1·64	1·21	·74	·36	·23
3	3·10	2·71	2 34	1·82	1·33	·81	·40	·25
3¼	3·37	2·96	2·52	1·96	1·44	·88	·43	·27
3½	3·65	3·21	2·76	2·11	1·56	·95	·46	·29
3¾	3·97	3·47	2·96	2 27	1·67	1·02	50	·31
4	4·24	3·70	3·18	2·43	1·79	1·09	·53	·33
4¼	4·51	3·95	3·39	2·59	1·90	1·16	·56	·36
4½	4·80	4·20	3 61	2 75	2·02	1·23	·60	·38
4¾	5·10	4·45	3·81	2·91	2·13	1·30	·63	·40
5	5·40	4·70	4·02	3·06	2·25	1·36	·67	·42
5¼	5·67	4·94	4·24	3 22	2·36	1·43	·70	44
5½	5·96	5·19	4·44	3·38	2·48	1·50	·73	·46
5¾	6·26	5·44	4·65	3·54	2·59	1·57	·77	·48
6	6·53	5·68	4·86	3·70	2·71	1·64	·80	·50

The hardness of aluminium varies according to its purity, the purest metal being the softest. Aluminium of 98 per cent. purity is about as hard as copper. Aluminium becomes sensibly harder the more it is worked, either by hammering, rolling, drawing, or stamping.

Aluminium may be cut nearly as easily as wood with either a circular-saw or a band-saw, efficiently lubricated with either turps, petroleum, tallow, or benzine. In turning or planing aluminium, it is necessary to take small cuts, and to continually lubricate with either turps, benzine, or petroleum. In filing aluminium, single-cut files are most efficient. The files may be cleaned by dipping in a solution of caustic soda, and afterwards washing them in running water, and drying them in sawdust. The proper speed for drilling aluminium lubricated with petroleum is given at page 217.

Aluminium Bronzes are tough and strong, and highly non-corrosive when exposed to sea-water.

An aluminium bronze composed of aluminium 10 per cent. and copper 90 per cent., has a tensile strength in castings of 30 tons per square inch, with an elongation of 22 per cent. in 4 inches. Its specific gravity is 7·65; and its melting point is 1753° Fahr.

An aluminium bronze composed of aluminium 7½ per cent., copper 90½ per cent., and silicon 2 per cent., has a tensile strength in castings of 27 tons per square inch, with an elongation of from 42 per cent. to 48 per cent. in 4 inches. Its specific gravity is 7·7. It is very tough and ductile, but its elastic limit in castings is only about 4 tons per square inch; when forged, rolled, or drawn, the elastic limit is 14 tons per square inch.

An aluminium bronze composed of aluminium 5 per cent. and copper 95 per cent., has a tensile strength in castings of 25 tons per square inch, with an elongation of from 50 per cent. to 60 per cent. in 4 inches. It has a very fine gold colour. Its specific gravity is 8·21.

An aluminium bronze composed of aluminium 2½ per cent. and copper 97½ per cent., has a tensile strength in castings of 20 tons per square inch, with an elongation of 40 per cent. in 4 inches. Its specific gravity is 8·31.

Weight of Aluminium Bronzes.—The nickel-aluminium in column A. of the following table is composed of 95 per cent. of aluminium and 5 per cent. of nickel.

The tungsten-aluminium in column B. is composed of 95 per cent. of aluminium and 5 per cent. of tungsten.

The aluminium-bronze in column C. is composed of 10 per cent. of aluminium and 90 per cent. of copper.

The aluminium-bronze in column D. is composed of 7½ per cent. of aluminium, 90½ per cent. of copper, and 2 per cent. of silicon.

The aluminium-bronze in column E. is composed of 5 per cent. of aluminium and 95 per cent. of copper.

The aluminium-bronze in column F. is composed of 2½ per cent. of aluminium and 97½ per cent. of copper.

The aluminium-brass in column G. is composed of 2 per cent. of aluminium, 60 per cent. of copper, and 40 per cent. of zinc.

Table 155.—Approximate Weight of One Square Foot of Cast Plates of Nickel-Aluminium, Tungsten-Aluminium, Various Aluminium-Bronzes, and of Rolled Plates of Aluminium-Brass.

Thickness of Plate.	Approximate Weight of One Square Foot of Nickel-Aluminium A	Approximate Weight of One Square Foot of Tungsten-Aluminium B	Approximate Weight of One Square Foot of Aluminium Bronze C	Approximate Weight of One Square Foot of Aluminium Bronze. D	Approximate Weight of One Square Foot of Aluminium Bronze. E	Approximate Weight of One Square Foot of Aluminium Bronze. F	Approximate Weight of one Square Foot of Aluminium-Brass. G
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1/16	·9	·94	2·48	2·5	2·67	2·7	2·72
3/32	1·3	1·41	3·74	3·7	4·00	4·1	4·08
1/8	1·8	1·88	4·96	5·0	5·34	5·4	5·44
5/32	2·2	2·35	6·20	6·2	6·67	6·7	6·80
3/16	2·7	2·82	7·44	7·5	8·01	8·1	8·16
7/32	2·11	3·29	8·68	8·7	9·34	9·4	9·52
1/4	3·6	3·76	9·92	10·0	10·68	10·8	10·88
9/32	4·0	4·23	11·16	11·2	12·01	12·1	12·24
5/16	4·5	4·70	12·40	12·5	13·35	13·5	13·60
11/32	4·9	5·17	13·64	13·7	14·68	14·8	14·96
3/8	5·4	5·64	14·88	15·0	16·02	16·2	16·32
13/32	6·8	6·11	16·12	16·2	17·35	17·5	17·68
7/16	6·3	6·58	17·36	17·5	18·69	18·9	19·04
15/32	6·7	7·05	18·60	18·7	20·02	20·2	20·40
1/2	7·2	7·52	19·84	20·0	21·36	21·6	21·76
9/16	8·1	8·46	22·32	22·5	24·03	24·3	24·48
5/8	9·0	9·40	24·80	25·0	26·70	27·0	27·20
11/16	9·9	10·34	27·28	27·5	29·36	29·7	29·92
3/4	10·8	11·28	29·76	30·0	32·04	32·4	32·64
13/16	11·7	12·22	32·24	32·5	34·70	35·1	35·36
7/8	12·6	13·16	34·72	35·0	37·38	37·8	38·08
15/16	13·5	14·10	37·20	37·5	40·04	40·5	40·80
1	14·4	15·04	39·68	40·0	42·71	43·2	43·52

Wolframinium is an alloy of wolfram, copper, and aluminium. Its specific gravity is 2·74. Its tensile strength is, when cast in sand, 10 tons per square inch; when cast in chills, from 12 to 13 tons per square inch; when forged, 15 tons per square inch; and when rolled or drawn, from 15 to 20 tons per square inch. Its elongation when hard is from 3 to 5 per cent.; and when annealed, from 10 to 20 per cent. It may be forged, rolled, and drawn either hot or cold; it takes a high polish, and does not tarnish.

Romanium is an alloy of wolfram, nickel, and aluminium. Its specific gravity is 2·75. Its tensile strength is equal to that of wolframinium, but it is much harder, and also of greater elasticity. It can be worked either hot or cold; forged, rolled, drawn, or stamped; and it is suitable for large castings, large plates and bars.

Table 156.—WEIGHT OF ONE FOOT IN LENGTH OF SEAMLESS DRAWN BRASS TUBES, CONTAINING 70 PER CENT. OF COPPER AND 30 PER CENT. OF ZINC. TENSILE STRENGTH, ANNEALED, ABOUT $13\frac{1}{2}$ TONS PER SQUARE INCH. (MUNTZ'S METAL CO., LIMITED.)

Imperial Standard Wire Gauge.	THICKNESS OF BRASS.							
	5	6	7	8	9	10	12	14
Inch.	·212 $\frac{7}{32}$ b	·192 $\frac{3}{16}$ f	·176 $\frac{11}{64}$ f	·160 $\frac{5}{32}$ f	·144 $\frac{9}{64}$	·128 $\frac{1}{8}$ f	·104 $\frac{7}{64}$ b	·08 $\frac{5}{64}$ f
External Diameter in Inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{3}{4}$	...	...	...	...	...	...	...	·62
$\frac{7}{8}$	...	...	...	...	...	...	·93	·74
1	...	...	...	...	...	...	1·08	·86
$1\frac{1}{8}$	...	...	...	...	...	1·49	1·24	·97
$1\frac{1}{4}$	...	...	...	...	...	1·67	1·39	1·09
$1\frac{3}{8}$	...	...	...	...	2·06	1·86	1·54	1·21
$1\frac{1}{2}$	...	...	...	...	2·27	2·04	1·69	1·32
$1\frac{5}{8}$	...	...	...	2·73	2·48	2·23	1·84	1·44
$1\frac{3}{4}$	...	...	...	2·96	2·69	2·42	1·99	1·56
$1\frac{7}{8}$	...	...	3·48	3·19	2·90	2·60	2·14	1·67
2	...	...	3·74	3·43	3·11	2·79	2·30	1·79
$2\frac{1}{8}$	...	4·32	3·99	3·66	3·32	2·98	2·45	1·90
$2\frac{1}{4}$	...	4·60	4·25	3·89	3·53	3·16	2·60	2·02
$2\frac{3}{8}$	5·34	4·88	4·51	4·13	3·74	3·35	2·75	2·14
$2\frac{1}{2}$	5·65	5·16	4·76	4·36	3·95	3·54	2·90	2·25
$2\frac{5}{8}$	5·96	5·44	5·02	4·59	4·16	3·72	3·05	2·37
$2\frac{3}{4}$	6·27	5·72	5·28	4·83	4·37	3·91	3·20	2·49
$2\frac{7}{8}$	6·57	6·00	5·33	5·06	4·58	4·09	3·36	2·60
3	6·88	6·28	5·79	5·29	4·79	4·28	3·51	2·72
$3\frac{1}{8}$	7·19	6·56	6·04	5·52	5·00	4·47	3·66	2·84
$3\frac{1}{4}$	7·50	6·84	6·30	5·76	5·21	4·65	3·81	2·95
$3\frac{3}{8}$	7·81	7·12	6·56	5·99	5·42	4·84	3·96	3·07
$3\frac{1}{2}$	8·12	7·40	6·81	6·22	5·63	5·03	4·11	3·19
$3\frac{5}{8}$	8·43	7·68	7·07	6·46	5·84	5·21	4·26	3·30
$3\frac{3}{4}$	8·73	7·95	7·32	6·69	6·05	5·40	4·42	3·42
$3\frac{7}{8}$	9·04	8·23	7·58	6·92	6·26	5·58	4·57	3·53
4	9·35	8·51	7·84	7·15	6·47	5·77	4·72	3·65
Factor	1·05	·86	·72	·60	·48	·38	·25	·14

NOTE.—To find the weight of a brass tube of a given internal diameter, add the factor at the bottom of the table to the weight of a tube of similar external diameter. For instance, the weight of a brass tube of 2 inches internal diameter, of 12 I.S.W.G. in thickness, is = 2·30 + ·25 = 2·55 pounds per foot in length.

For brass tubes composed of 2 parts of copper and 1 part of zinc, multiply the weights of brass tubes in the above table by ·994.

Table 157.—WEIGHT OF ONE FOOT IN LENGTH OF SEAMLESS DRAWN COPPER TUBES. (MUNTZ'S METAL CO., LIMITED.)

Imperial Standard Wire-Gauge.	THICKNESS OF COPPER.							
	0000	00	1	3	6	8	10	13
Inch.	·400 13/32 b	·348 11/32 f	·300 19/64 f	·252 1/4 f	·192 3/16 f	·160 5/32 f	·128 1/8 f	·092 3/32
Internal Diameter in Inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
½	4·35	3·57	2·90	2·29	1·61	1·28	·97	·66
¾	5·56	4·62	3·81	3·05	2·19	1·76	1·36	·94
1	6·77	5·67	4·72	3·82	2·77	2·24	1·75	1·21
1¼	7·98	6·73	5·62	4·58	3·35	2·73	2·13	1·49
1½	9·19	7·78	6·53	5·34	3·93	3·21	2·52	1·77
1¾	10·40	8·83	7·44	6·10	4·51	3·70	2·91	2·05
2	11·61	9·88	8·35	6·86	5·09	4·18	3·29	2·33
2¼	12·82	10·94	9·25	7·63	5·67	4·66	3·68	2·61
2½	14·03	11·99	10·16	8·39	6·25	5·15	4·07	2·88
2¾	15·24	13·04	11·07	9·15	6·83	5·63	4·46	3·16
3	16·45	14·09	11·98	9·91	7·41	6·12	4·84	3·44
3¼	17·66	15·15	12·88	10·68	7·99	6·60	5·23	3·72
3½	18·87	16·20	13·79	11·44	8·58	7·08	5·62	4·00
3¾	20·08	17·25	14·70	12·20	9·16	7·57	6·00	4·28
4	21·29	18·30	15·61	12·96	9·74	8·05	6·39	4·55
4¼	22·50	19·36	16·51	13·72	10·32	8·54	6·78	4·83
4½	23·71	20·41	17·42	14·49	10·90	9·02	7·17	5·11
4¾	24·92	21·46	18·33	15·25	11·48	9·50	7·55	5·39
5	26·13	22·51	19·23	16·01	12·06	9·99	7·94	5·67
5¼	27·34	23·57	20·14	16·77	12·64	10·47	8·33	5·95
5½	28·55	24·62	21·05	17·54	13·22	10·96	8·71	6·22
5¾	29·76	25·67	21·96	18·30	13·80	11·44	9·10	6·50
6	30·97	26·72	22·86	19·06	14·38	11·92	9·49	6·78
6½	33·39	28·83	24·68	20·58	15·54	12·89	10·26	7·34
7	35·81	30·93	26·49	22·11	16·70	13·86	11·04	7·89
7½	38·23	33·04	28·31	23·63	17·87	14·83	11·81	8·45
8	40·65	35·14	30·12	25·16	19·03	15·79	12·59	9·01
8½	43·07	37·25	31·94	26·68	20·19	16·76	13·36	9·56
9	45·49	39·35	33·75	28·21	21·35	17·73	14·13	10·12
9½	47·91	41·46	35·57	29·73	22·51	18·70	14·91	10·68
10	50·33	43·56	37·38	31·25	23·67	19·67	15·68	11·23
10½	52·75	45·67	39·20	32·78	24·83	20·63	16·46	11·79
11	55·16	47·77	41·01	34·30	26·00	21·60	17·23	12·34
11½	57·58	49·88	42·83	35·83	27·16	22·57	18·01	12·90
12	60·00	51·98	44·64	37·35	28·32	23·54	18·78	13·46
12½	62·42	54·09	46·45	38·88	29·48	24·50	19·55	...
13	64·84	56·19	48·27	40·40	30·64	25·47	20·33	...
14	69·68	60·40	51·90	43·45	32·96	27·41	21·88	...
Factor	3·87	2·93	2·18	1·54	·89	·62	·40	·20

To find the weight of a copper tube of a given external diameter, subtract the factor at the bottom of the Table from the weight of a tube of similar internal diameter. For instance, the weight of a copper tube 2 inches external diameter, of 10 I.S.W.G. in thickness, is = 3·29 − ·40 = 2·89 pounds per foot in length.

The Tenacity of Ordinary Copper Tubes is about 15 tons per square inch.

A copper tube by Muntz's Metal Company, Limited, was analysed and found to consist of 99·86 per cent. of copper; ·013 per cent. of arsenic; ·021 per cent. of antimony; ·030 per cent. of bismuth; ·030 per cent. of lead; ·007 per cent. of iron; and traces of silver and nickel.

Specially hardened copper tubes are made for locomotive boilers. They are nearly twice as durable as brass tubes, and have a higher heat-conductivity. Their tensile strength is from 20 to 22 tons per square inch.

Table 158.—APPROXIMATE WEIGHT OF ONE FOOT IN LENGTH OF CAST GUN-METAL TUBES OR CYLINDERS FOR BUSHES OR BEARINGS OF SHAFTS. COMPOSITION COPPER 84 PER CENT. AND TIN 16 PER CENT.

Internal Diameter in Inches.	THICKNESS OF GUN-METAL TUBE IN INCHES.							
	¼	5/16	⅜	7/16	½	⅝	¾	⅞
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	3·64	4·80	6·03	7·35	8·76	11·87	15·36	19·16
1½	5·12	6·65	8·22	9·90	11·69	15·59	19·76	24·28
2	6·57	8·44	10·40	12·50	14·64	19·16	24·16	29·40
2½	8·04	10·27	12·62	15·00	17·50	22·85	28·45	34·51
3	9·50	12·14	14·76	17·62	20·47	26·42	33·18	39·63
3½	10·95	13·93	17·02	20·12	23·33	30·11	37·25	44·75
4	12·38	15·71	19·16	22·73	26·30	33·80	41·65	49 87
4½	13·93	17·62	21·42	26·30	29·16	37·49	46 06	54·98
5	15·36	19·40	23·57	27·85	32·13	41·06	50·34	60·10
5½	16·78	21·19	25·71	30·35	35·11	44·75	54·74	65·22

Internal Diameter in Inches.	THICKNESS OF GUN-METAL TUBE IN INCHES.							
	½	⅝	¾	⅞	1	1⅛	1¼	1½
lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
6	38·08	48·44	59·15	70·33	81·76	93·66	105·9	119·6
6½	40·94	52·00	63·58	75·44	87·59	100·20	113·2	139·9
7	43·79	55·70	67·95	80·57	93·42	106·75	120·5	149·3
7½	46·77	59·39	72·36	85·57	99·37	113·41	127·8	156·2
8	49·63	62·96	76·64	90·68	105·20	120·00	135 1	166·4
8½	52·60	66·53	81·04	95·80	111·03	126·50	142·5	175·5
9	55·45	70·21	85·45	100·90	116·86	133·05	149·7	184·0
10	61·29	77·47	94·25	111·15	129·71	146·26	164·4	201·0
11	67·24	84·73	102·94	121·39	140·19	159·35	178·9	218·6
12	73·10	92·23	111·75	131·62	151·85	172·56	194·0	237·3

Table 159.—Approximate Weight in Pounds of One Foot in Length of Cast anti-friction White-Metal Tubes or Cylinders for Bushes or Bearings of Shafts and other purposes, representing the Average Weight of several Compositions of Tin, Antimony, and Copper.

Internal Diameter in Inches.	Thickness of Anti-Friction White-Metal Tule in Inches.							
	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	3·2	4·2	5·3	6·4	7·6	10·3	13·4	16·7
1½	4·5	5·8	7·2	8·6	10·2	13·6	17·2	21·1
2	5·7	7·4	9·1	10·9	12·7	16·5	21·0	25·5
2½	7·0	8·9	11·0	13·0	15·2	19·8	24·7	30·0
3	8·3	10·6	12·8	15·3	17·8	22·4	28·5	34·4
3½	9·5	12·1	14·8	17·5	20·3	26·1	32·3	38·8
4	10·8	13·7	16·7	19·8	22·9	29·3	36·2	43·3
4½	12·1	15·3	18·6	22·8	25·3	32·5	40·0	47·7
5	13·4	16·9	20·5	24·2	27·9	35·6	43·7	52·2
5½	14·6	18·4	22·3	26·4	30·5	38·8	47·5	56·6

Internal Diameter in Inches.	Thickness of Anti-Friction White-Metal Tube in Inches.							
	1/2	5/8	3/4	7/8	1	1⅛	1¼	1½
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
6	33·1	42·0	51·3	61·1	70·9	81·3	91·9	114·0
6½	35·5	45·1	55·1	65·5	76·0	86·9	98·2	121·4
7	38·0	48·3	59·0	70·0	81·0	92·6	104·5	129·5
7½	40·6	51·5	61·8	74·2	86·2	98·4	111·0	136·2
8	43·1	54·6	66·5	78·7	91·3	104·0	117·2	143·5
8½	45·7	57·7	70·3	83·1	96·3	109·8	123·6	151·3
9	48·1	60·9	74·1	87·5	101·4	115·4	130·0	159·5
10	53·2	67·2	81·8	96·4	111·5	126·9	142·5	174·4
11	58·4	73·5	89·3	105·3	121·6	138·2	155·1	189·0
12	63·4	80·0	96·9	114·2	131·7	149·7	167·8	205·0

Table 160.—Weight of One Foot in Length of Small Wrought-iron Tubes.

Internal Diameter.	Thickness of Wrought-Iron Tubf in Inches.							
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2
Inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
¼	·21	·52	·91	1·32	1·91	2·48	3·10	3·86
½	·41	·85	1·42	2·08	2·72	3·52	4·31	5·27
¾	·51	1·21	1·88	2·63	3·51	4·54	5·52	6·58
1	·71	1·52	2·39	3·28	4·31	5·46	6·57	7·86

Table 161.—WEIGHT OF ONE FOOT IN LENGTH OF NAVAL-BRASS TUBES.

Imperial Standard Wire Gauge.	THICKNESS OF NAVAL-BRASS.							
	6	8	10	12	14	16	18	20
Inch.	·192	·160	·128	·104	·080	·064	·048	·036
Internal Diameter in Inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{2}$	1·53	1·20	·93	·73	·53	·42	·31	·22
$\frac{3}{4}$	2·08	1·68	1·29	1·02	·76	·60	·44	·33
1	2·63	2·13	1·67	1·32	·99	·79	·58	·43
$1\frac{1}{4}$	3·19	2·60	2·03	1·62	1·23	·97	·72	·54
$1\frac{1}{2}$	3·74	3·05	2·40	1·92	1·46	1·15	·86	·64
$1\frac{3}{4}$	4·29	3·51	2·77	2·22	1·68	1·33	·99	·74
2	4·84	3·97	3·13	2·52	1·91	1·52	1·13	·85

Weight of Wrought-Iron Tubes for Gas, Steam, and Water.—These tubes have distinctive colours. Water tubes are painted blue, steam tubes red, and gas tubes are black.

Water tubes are one gauge thicker than gas tubes, and steam tubes are two gauges thicker than gas tubes.

All tubes are tested by hydraulic pressure as follows:—Black gas tubes, 100 lbs.; galvanized gas tubes, 300 lbs.; blue water tubes, 200 lbs.; galvanized water tubes, 400 lbs.; red steam tubes, 500 lbs.; galvanized steam tubes, 500 lbs. per square inch.

Table 162.—WEIGHT OF WROUGHT-IRON TUBES FOR GAS AND STEAM.

Internal diam , nominal............Ins.	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$
External diam., measurement, Ins.	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{13}{16}$	$1\frac{1}{16}$	$1\frac{5}{16}$	$1\frac{5}{8}$	$1\frac{7}{8}$
Thickness, gas tubes, wire gauge No.	14	14	13	12	11	10	9	8
„ steam tubes „ „ No.	12	12	11	10	9	8	7	6
Approx. weight, gas, lbs., per ft.	0·27	0·40	0·58	0·82	1·21	1·69	2·47	3·06
„ „ steam „ „	0·30	0·44	0·67	0·94	1·48	2·03	2·92	3·59
Length of screw on tubes ....Ins.	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	1	1
Pitch of screw, No. of threads per in.	28	18	18	14	14	11	11	11
Internal diam., nominal ....Ins.	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{2}$	4
External diam., measurement, Ins.	$2\frac{1}{16}$	$2\frac{3}{8}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	4	$4\frac{1}{2}$
Thickness, gas tubes, wire gauge No.	8	8	7	7	7	7	7	7
„ steam tubes „ „ No.	6	5	5	5	5	5	5	5
Approx. weight, gas, lbs., per ft.	3·38	3·89	4·88	5·36	5·89	6·37	7·34	8·33
„ „ steam „ „	3·97	5·04	5·74	6·29	6·85	7·40	8·50	9·60
Length of screw on tubes ....Ins.	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{3}{8}$	$1\frac{5}{8}$	$1\frac{3}{4}$
Pitch of screw, No. of threads per in.	11	11	11	11	11	11	11	11

Galvanizing tubes increases their weight from 3 to 6 per cent. It is a great preservative against rust, and renders the tubes extremely durable, but the process of galvanizing makes the iron somewhat brittle.

Table 163.—WEIGHT OF ONE FOOT IN LENGTH OF LAP-WELDED WROUGHT-IRON TUBES.

Imperial Standard Wire Gauge.	THICKNESS OF WROUGHT-IRON TUBES.							
	1	3	5	6	7	8	9	10
Inch.	·300 $\frac{19}{64}$ f	·252 $\frac{1}{4}$ f	·212 $\frac{7}{32}$ b	·192 $\frac{3}{16}$ f	·176 $\frac{11}{64}$	·160 $\frac{5}{32}$ f	·144 $\frac{9}{64}$ f	·128 $\frac{1}{8}$ f
External Dia. in Inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	2·199	1·974	1·749	1·624	1·519	1·407	1·291	1·169
1⅛	2·592	2·304	2·027	1·876	1·749	1·617	1·479	1·336
1¼	2·984	2·634	2·304	2·127	1·979	1·826	1·668	1·504
1⅜	3·377	2·963	2·582	2·378	2·210	2·036	1·856	1·671
1½	3·770	3·293	2·859	2·630	2·440	2·245	2·045	1·839
1⅝	4·163	3·623	3·137	2·881	2·671	2·455	2·233	2·007
1¾	4·555	3·953	3·414	3·132	2·901	2·664	2·422	2·174
1⅞	4·948	4·283	3·692	3·384	3·131	2·873	2·610	2·342
2	5·341	4·613	3·969	3·635	3·362	3·083	2·799	2·509
2⅛	5·733	4·943	4·247	3·886	3·592	3·292	2·987	2·677
2¼	6·126	5·273	4·524	4·138	3·822	3·502	3·176	2·844
2⅜	6·519	5·602	4·802	4·389	4·053	3·711	3·364	3·012
2½	6·911	5·932	5·079	4·640	4·283	3·921	3·553	3·179
2⅝	7·304	6·262	5·357	4·892	4·514	4·130	3·741	3·347
2¾	7·697	6·592	5·634	5·143	4·744	4·339	3·930	3·514
2⅞	8·090	6·922	5·912	5·394	4·974	4·549	4·118	3·682
3	8·482	7·252	6·189	5·646	5·205	4·758	4·307	3·850
3¼	9·268	7·911	6·744	6·148	5·665	5·177	4·684	4·185
3½	10·053	8·571	7·299	6·651	6·126	5·596	5·061	4·520
3¾	10·838	9·231	7·854	7·154	6·587	6·015	5·438	4·855
4	11·624	9·891	8·410	7·656	7·048	6·434	5·815	5·190
4¼	12·409	10·550	8·965	8·159	7·509	6·853	6·192	5·525
4½	13·195	11·210	9·520	8·662	7·969	7·272	6·569	5·860
4¾	13·980	11·870	10·075	9·164	8·430	7·690	6·946	6·195
5	14·765	12·53	10·630	9·667	8·891	8·109	7·323	6·530
5¼	15·551	13·189	11·185	10·170	9·352	8·528	7·700	6·866
5½	16·336	13·849	11·740	10·672	9·812	8·947	8·077	
5¾	17·122	14·509	12·295	11·175	10·273	9·366	8·454	
6	17·907	15·169	12·850	11·678	10·734	9·785	8·831	
6½	19·478	16·488	13·960	12·683	11·655	10·623	9·585	
7	21·048	17·807	15·070	13·688	12·577	11·460	10·339	
7½	22·619	19·127	16·180	14·694	13·499			
8	24·190	20·446	17·290	15·699	14·420			
8½	25·761	21·766	18·400	16·710	15·345			
9	27·332	23·085	19·510	17·722	16·290			
9½	28·903	24·405	20·62	18·738	17·255			
10	30·463	25·724	21·73	19·760	18·240			
10½	32·17	26·88						
11	34·00	28·15						
11½	35·95	29·45						
12	38·00	30·80						

Table 164.—APPROXIMATE WEIGHT OF ONE FOOT IN LENGTH OF SEAMLESS MILD-STEEL TUBES.

Imperial Standard Wire Gauge.	THICKNESS OF MILD-STEEL TUBES.							
	1	3	5	6	7	8	9	10
Inch.	·300 19/64 f	·252 1/4 f	·212 7/32 b	·192 3/16 f	·176 11/64	·160 5/32 f	·144 9/64 f	·128 1/8 f
External Dia. in Inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	2·25	2·01	1·78	1·66	1·55	1·44	1·22	1·19
1 1/8	2·65	2·35	2·07	1·92	1·79	1·65	1·51	1·36
1 1/4	3·05	2·69	2·35	2·17	2·02	1·87	1·70	1·53
1 3/8	3·45	3·03	2·64	2·43	2·26	2·08	1·89	1·71
1 1/2	3·85	3·36	2·92	2·68	2·49	2·30	2·09	1·88
1 5/8	4·25	3·70	3·20	2·94	2·73	2·51	2·28	2·05
1 3/4	4·65	4·04	3·48	3·20	2·96	2·72	2·47	2·21
1 7/8	5·05	4·37	3·77	3·45	3·19	2·94	2·66	2·39
2	5·45	4·71	4·05	3·71	3·43	3·15	2·86	2·56
2 1/8	5·85	5·05	4·34	3·97	3·67	3·36	3·05	2·73
2 1/4	6·25	5·38	4·61	4·22	3·90	3·58	3·24	2·90
2 3/8	6·66	5·72	4·90	4·48	4·14	3·79	3·43	3·07
2 1/2	7·06	6·06	5·18	4·74	4·37	4·00	3·63	3·24
2 5/8	7·46	6·39	5·47	5·00	4·61	4·22	3·82	3·42
2 3/4	7·86	6·73	5·75	5·25	4·84	4·43	4·01	3·58
2 7/8	8·26	7·07	6·04	5·51	5·08	4·65	4·20	3·76
3	8·68	7·40	6·32	5·76	5·31	4·86	4·40	3·93
3 1/4	9·46	8·08	6·89	6·28	5·78	5·29	4·78	4·27
3 1/2	10·27	8·75	7·45	6·79	6·25	5·71	5·17	4·61
3 3/4	11·07	9·42	8·02	7·30	6·73	6·14	5·55	4·95
4	11·87	10·10	8·59	7·82	7·20	6·57	5·94	5·30
4 1/4	12·67	10·77	9·15	8·33	7·67	7·00	6·32	5·64
4 1/2	13·47	11·44	9·24	8·84	8·14	7·42	6·70	5·98
4 3/4	14·27	12·11	10·29	9·36	8·61	7·85	7·09	6·32
5	15·08	12·79	10·85	9·87	9·08	8·28	7·48	6·67
5 1/4	15·87	13·46	11·42	10·38	9·45	8·71	7·86	7·01
5 1/2	16·68	14·14	11·98	10·90	10·02	9·13	8·25	
5 3/4	17·48	14·81	12·55	11·41	10·49	9·56	8·63	
6	18·28	15·49	13·12	11·92	10·96	10·00	9·02	
6 1/2	19·89	16·83	14·25	12·95	11·90	10·85	9·79	
7	21·49	18·18	15·39	13·98	12·84	11·70	10·56	
7 1/2	23·09	19·53	16·52	15·00	13·78			
8	24·70	20·88	17·65	16·03	14·72			
8 1/2	26·30	22·22	18·79	17·06	15·67			
9	27·91	23·57	19·92	18·10	16·63			
9 1/2	29·50	24·92	21·05	19·13	17·62			
10	31·10	26·26	22·19	20·18	18·63			
10 1/2	32·85	27·44						
11	34·71	28·74						
11 1/2	36·70	30·07						
12	38·80	31·72						

Mild-Steel Riveted Pipes or Tubes.—Particulars and weights are given in the three following Tables of some riveted pipes constructed of mild-steel.

The weight, thickness, and working head of the pipes are calculated by the following formulæ:—

Let W = weight in lbs. per lineal foot.
d = diameter in inches.
w = weight of plate in pounds per square foot.
t = thickness of pipe in inches.
H = working head in feet of water.

The weight of steel pipes per lineal foot, $W = d \times w \times {\cdot}33$.

The thickness of pipes and working head of pressure are,

$$\text{Cast-iron Pipes} \begin{cases} t = {\cdot}00012\, dH \\ H = \dfrac{t}{{\cdot}00012\, d} \end{cases} \qquad \text{Steel Pipes} \begin{cases} t = {\cdot}000025\, d\, H \\ H = \dfrac{t}{{\cdot}000025\, d} \end{cases}$$

Table 165.—Relative Thickness of Riveted Pipes or Tubes for equal Strength.

Description.	Cast-Iron.	Wrought-Iron.	Steel.
Weight of 1 square foot, 1 inch thick	37·5 lbs.	40 lbs.	40·8 lbs.
Tenacity per square inch	18000 lbs.	48600 lbs.	72000 lbs.
Relative strength for equal thicknesses	1	2·7	4
Factor of safety	10	6	5
Relative strength due to factor of safety	1	4·5	8
Reduction in strength due to riveted joints	—	30 per cent.	30 per cent.
Relative strength after reduction for riveted joints	1	3·15	5·6
Relative thickness for plates of equal strength	1	·3174	·1786

Table 166.—Relative Weight of Pipes or Tubes for equal Strength.

Description.	Cast-Iron.	Wrought-Iron.	Steel.
Thickness of plates, weighing 40 lbs. per square foot	1·066 inches.	1 inch.	·9804 inch.
Relative strength for equal weight	1	2·533	3·678
Relative strength due to factor of safety	1	4·22	7·356
Relative strength after reduction for riveted joints	1	2·955	5·149
Relative weight of plain cylinders of equal strength	1	·3384	·1942
Increase in weight of pipes due to socket and spigot joints	5·8 per cent.	15 per cent.	15 per cent.
Relative weight of pipes of equal strength	1	·3678	·2111

The longitudinal seams of the pipes are double riveted, and are estimated to have 70 per cent. of the strength of the solid undrilled plates. The pipes are united in lengths of from 4 to 6 feet with circular seams of single-riveting.

Table 165 shows that the resistance to bursting of riveted steel-pipes of the given strength may be 5·6 times that of cast-iron pipes of equal thickness.

Table 167.—Weight of One Foot in Length of Riveted Steel-Pipes or Tubes, with Plain Ends.

Internal Diameter.	Thickness of the Steel Pipe.							
	3/32 inch.	1/8 inch.	3/16 inch.	1/4 inch.	5/16 inch.	3/8 inch.	1/2 inch.	5/8 inch.
Inches.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
3	4·05							
4	5·13							
5	6·21							
6	7·29							
7	8·37							
8	9·45							
9	10·53	14·48						
10	11·61	15·95						
11	12·69	17·42						
12	13·77	18·89	29·83	40·5				
13	14·85	20·36	32·01	43·3				
14	15·93	21·83	34 20	46·2				
15	17·01	23·30	36·37	49·0	60·3			
16	18·10	24·77	38·56	51·8	63 9			
17		26·24	40·74	54·7	67·5			
18		27·71	42 93	57·5	71·0	85·7		
19		29·18	45 11	60·4	74·6	90·0		
20		30·65	47·30	63·2	78·3	94·3		
21		32·12	49·48	66·1	81·8	98·6		
22		33·59	51·67	68·9	85·4	102·9		
23		35·06	53·85	71·8	89·0	107·2		
24		36 53	56·04	74 6	92·6	111·5	149·0	186·7
25			58·22	77·5	96·2	115·8	154·7	193·8
26			60·41	80·3	99·8	120·1	160·4	200·9
27			62·60	83·1	103·4	124·4	166·1	208·0
28			64·78	86·0	107·0	128·7	171·8	215·1
29			66·96	88·8	110·6	133·0	177·5	222·2
30			69·15	91·7	114·2	137·3	183·2	229·3
31				94 5	117·8	141 6	188 9	236·4
32				97·4	121·4	145·9	194·6	243·5
33				100·2	125·0	150·2	200·3	250·6
34				103·0	128 6	154·5	206·0	257·8
35				105·9	132·2	158·8	211·7	264·9
36				108·7	135·8	163·1	217·4	272·0

Table 168.—Breaking-Strength of Materials in Tons per Square Inch.

Description of Materials.	Breaking Strain in Tension per Square Inch in Tons	Breaking Strain in Compression per Square Inch, in Tons
Cast-steel bars, rolled and forged	52	
Shear-steel bars ditto	50	
Bessemer-steel bars ditto	48	
Blistered-steel bars ditto	45	
Spring-steel bars ditto	32	
Steel boiler plates ditto	32	18
Lowmoor or best Yorkshire bar iron	26	12
Ordinary good merchant bar-iron	25	12
Hoop-iron, best quality, average	25	
Lowmoor or best Yorkshire iron plates along the fibre	24	
ditto ditto ditto across the fibre	22	
Ordinary good angle and tee-iron	22	
Ordinary good boiler-plates along the fibre	21	
ditto ditto across the fibre	18	
Ordinary good ship-plates along the fibre	20	
ditto ditto across the fibre	17	
Cast-iron, best quality	7	48
ditto ordinary average quality	6	42
Malleable cast-iron, best quality	20	
Phosphor-bronze wire, not annealed	55	
Steel wire, not annealed, best quality	53	
Brass wire ditto, best quality	36	
Iron wire, best quality	28	
Copper wire	28	
Homogeneous metal bars, best	40	
Muntz metal . 3 copper; 2 zinc	22	
Sterro metal	27	
Brass tubes . 70 copper; 30 zinc	13½	
Railway rails, iron flange	20	
ditto iron double-headed	24	
ditto steel flange	34	
ditto ditto double headed	44	
Railway-wheel steel tires	42	
Aluminium-bronze	32	58
Phosphor-bronze	25	
Palladium wire	23	
Nickel	20	
Cobalt	18	
Copper, wrought	15	
Copper, cast	9	
Gun-metal and bronze	14	6
Brass	8	4·5
Soft solder	3·2	
Zinc, cast	3·1	

Table 168 *continued.*—BREAKING-STRENGTH OF MATERIALS.

Description of Materials.	Breaking Strain in Tension per Square Inch, in Tons.	Breaking Strain in Compression per Square Inch, in Tons.
Tin, cast	2	
Bismuth, cast	1·42	
Lead pipe	1·00	
Lead, sheet	·86	
Lead, cast	·81	
Antimony	·46	
Glass	1	13
Ebony, West Indian	...	8½
Iron-wood, West Indian	...	7¾
Lime tree	10⅝	
Lancewood	10½	3
Hornbeam	9	3¼
Apple tree	8¾	2¾
Boxwood	8⅛	4½
Ash	7	4
Birch	6½	2¾
Alder	6¼	3
Teak	6	5
Sycamore	5¾	3
Oak, English	5	4
Mahogany, Honduras	5	3
Lignumvitæ	5	4¼
Beech	5	4
Cedar	5	3
Yew	3½	
Mahogany, Spanish	3	2
Walnut and pine, each	3	2
Granite	...	4½
Sandstone	...	2½
Pressed bricks	...	1
Stock bricks	...	·90
Leather belting, best quality	1·50	
Stitched cotton belting, best quality	3·04	
Solid-woven cotton belting, best stout quality	4·65	
Hemp, twisted ¼ to 1 inch thick	4	
ditto 1 to 3 ditto	3	
ditto 3 to 5 ditto	2·4	
ditto 5 to 7 ditto	2·18	

NOTE.—The strength of steel is diminished to the extent of from 25 to 50 per cent. by annealing, and its strength is increased from 15 to 60 per cent. by hardening in oil.

Specific Gravity.—The specific gravity of a body, is its weight in proportion to an equal bulk of pure water, and the standard of comparison for solids and liquids is a cubic foot of pure water at 62° F., which weighs 1,000 ounces avoirdupois.

Table 169.—SPECIFIC GRAVITY AND WEIGHT OF MATERIALS, AND OF LIQUIDS AND GASES.

	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	lbs.
METALS.		
Platinum	21·526	1344
Gold	19·258	1204
Mercury	13·596	847
Lead	11·366	710
Silver	10·511	656
Bismuth	9·900	618
Copper, sheet	8·806	549
Gun metal	8·731	544
Copper, cast	8·610	538
Brass, cast	8·400	525
Nickel, cast	8·280	515
Steel	7·856	490
Wrought iron	7·700	480
Tin	7·294	455
Cast iron	7·218	450
Zinc, cast	6·862	428
Antimony	6·712	419
Arsenic	5·763	360
Aluminium, cast	2·560	160
MINERALS, ETC.		
White lead	3·164	198
Slate	2·834	176
Chalk	2·782	174
Marble	2·730	170
Glass, plate	2·700	168
Granite	2·662	166
Stone, mean of various	2·560	160
Stone, paving	2·416	151
Stonework	2·225	140
Stone, Bath	2·100	131
Brick and concrete . . . . each	2·000	125
Sand, pure, and common clay . each	1·900	119
Mortar and gravel . . . . each	1·760	110
Brickwork and earth . . . . each	1·750	109
Mud	1·600	100
Coal	1·280	80
Coke, hard	·750	46
Gas coke	·360	22
Snow, fresh	·096	6
Ice at 32°	·93	58
Melting ice	·92	57·4
Gutta percha	·97	60·5
Caoutchouc	·93	58·0
Gunpowder	·94	58·6

Table 169 *continued.*—SPECIFIC GRAVITY AND WEIGHT OF MATERIALS.

	Specific Gravity.	Weight of One Cubic Foot.
	Water = 1.	lbs.
LIQUIDS, ETC.		
Sea water	1·027	64
Tar from wood	1·015	63·43
Vinegar, distilled	1·009	68·00
Water, distilled	1·000	62·355
Tallow and linseed oil . . . each	·940	58·600
Rape seed oil	·921	57·4
Spirits, proof	·920	57·4
Olive oil	·915	57·0
Petroleum	·880	54·9
Turpentine	·870	54·2
Naphtha	·850	53·1
WOOD		
Lignum vitæ	1·33	82·9
Box, Dutch	1·32	82·3
Ebony	1·20	74·8
Heart of oak	1·17	73·0
Rosewood and lancewood	1·03	64·2
Oak, English	·93	58·0
Laburnum and hawthorn . . each	·920	57·38
Beech and Spanish mahogany . each	·850	53·1
Ash and plum tree . . . each	·840	52·5
Hornbeam, holly and crab tree . each	·760	47·5
Teak and maple . . . . each	·750	46·8
Birch, pear tree and apple tree . each	·730	45·5
Pine, pitch	·730	45·5
Pine, red	·670	41·8
Pine, white	·460	28·7
Pine, yellow	·450	27·2
Yew	·740	46·1
Cherry tree	·715	45·0
Walnut and plane tree, and elm . each	·670	41·8
Chestnut tree	·610	38·0
Mahogany, Honduras; and cedar each	·560	34·8
Larch	·530	31·0
Poplar	·384	24·0
Cork and charcoal . . . . each	·240	15·0
GASES, AT 32° F.		
Atmospheric air being	1·000	·0807
Nitrogen	·973	·0786
Gaseous steam	·622	·0502
Ammoniacal gas	·588	·0474
Hydrogen	·070	·0056
Carbonic acid	1·527	1232
Sulphurous acid	2·247	·1815

Table 170.—BULK OR STOWAGE CAPACITY PER TON OF VARIOUS SUBSTANCES.

Description of Goods.	Bulk of One Ton in Cubic Feet
Hay, old and compact, and straw	280
Furniture	260
Cotton, partly pressed	240
Cotton waste	210
Peat	200
Wool	180
Branches of trees ; also cork	150
Branches of trees tied in bundles	140
Wood, dry lumber	135
Vegetables	130
Cases of fruit	128
Cases of eggs	120
Grass	110
Stores, commissariat	100
Flax and hemp	95
Pressed cotton	90
Coke	80
Groceries and drugs in cases	80
Yellow pine wood	80
Sugar, soap and seeds in cases	75
White pine wood	70
Honduras mahogany	65
Red pine and walnut . . . . each	53
Wheat	50
Birch, pear tree, and pitch pine . . . . . each	49
Teak and maple . . . . ”	48
Hornbeam and crabtree . . . . . . ”	47
Coal	45
Ash and plum tree	43
Beech and Spanish mahogany	42
Oak, English	40
Oil	40
Tallow	39
Ice	39
Water	36
Towns sewage	36
Machinery in cases	35
Ebony	30
Box, Dutch	28
Cutlery in cases	28
Loose earth	28
Lignum vitæ	27
Sand	24
Brickwork and gravel . . . . each	20

Table 170 *continued.*—BULK OR STOWAGE CAPACITY PER TON OF VARIOUS SUBSTANCES.

Description of Goods.	Bulk of One Ton in Cubic Feet.
Rubble masonry, clay, and salt . . . . . . each	19
Roman cement	19
Bricks and tiles	18
Bath stone and concrete . . . . . . each	17
Graphite and lias . . . . „	16
Portland and Derby stone . . . . „	15
Paving quartz and sandstone . . . . . „	15
Yorkshire stone and chalk . . . . . . „	14½
Purbeck and millstone . . . . „	14
Granite and Kentish rag . . . . . . „	13½
Marble and limestone, and slate . . „	13
Clydesdale iron ore	12
Brown iron ore	9½
Red iron ore	7
Iron, cast in pigs	6¼
White-metal, cast in pigs	6
Bronze and gun-metal, cast in pigs	5½
Copper, cast in pigs	5
Lead, cast in pigs	4

Table 171—WEIGHT OF LIQUIDS.

	Weight of Water = 1000.	Weight per Gallon in lbs.
Acid, sulphuric	1850	18·5
Acid, nitric	1271	12·7
Acid, muriate	1200	12·0
Alcohol of commerce . .	825	8·2
Alcohol, proof spirit . .	922	9·2
Oil, linseed	940	9·4
Oil, whale	923	9·2
Oil, turpentine	870	8·7
Naphtha	848	8·5
Petroleum	878	8·8
Tar	1015	10·1
Water, distilled . . .	1000	10·0
Vinegar	1009	10·1

Barrels.—To find the contents of a barrel in imperial gallons: first square the centre diameter in inches, and then multiply it by 2, to which add the square of the diameter of the end in inches; then multiply this by the length of the cask in inches, and divide by 1122.

Table 172.—APPROXIMATE POWER REQUIRED TO DRIVE SELF-ACTING MACHINE-TOOLS WHEN CUTTING METAL AT AN AVERAGE SPEED, WITH AN AVERAGE RATE OF TRAVERSE, OR FEED.

Description of Self-acting Machine-Tool.	Approximate Indicated Horse-Power required to drive the Machine-Tool.	
	When working with a light cut.	When working with a heavy cut.
	I.H.P.	I.H.P.
6½ inches centre self-acting lathe	·10	·15
8½ Ditto ditto ditto	·14	·20
10 Ditto ditto ditto	·20	·28
12 Ditto ditto ditto	·24	·35
16 Ditto ditto ditto	·34	·50
18 Ditto ditto ditto	·40	·60
24 Ditto ditto ditto	·52	·80
30 Ditto ditto ditto	·60	·90
36 Ditto ditto ditto	·70	1·05
Face-lathe, turning 8 feet diameter	·77	1·15
Ditto ditto 20 ditto	1·67	2·50
Railway-wheel lathe, turning 5 feet diameter . . .	·80	1·20
Ditto ditto ditto 7 ditto . . .	1·24	1·85
Planing machine to plane 6 ft. long and 2 ft. 6 in. wide.	·33	·50
Ditto ditto ditto 10 ditto 3 0 ditto .	·60	·90
Ditto ditto ditto 20 ditto 4 0 ditto .	1·07	1·60
Ditto ditto ditto 25 ditto 5 3 ditto .	1·30	1·95
Ditto ditto ditto 30 ditto 6 6 ditto .	1·93	2·89
10 inches stroke shaping machine	·19	·28
12 Ditto ditto ditto	·33	·50
18 Ditto ditto ditto	·44	·65
24 Ditto ditto ditto	·67	1·00
10 inches stroke slotting machine	·33	·50
12 Ditto ditto ditto	·40	·60
18 Ditto ditto ditto	·47	·70
24 Ditto ditto ditto	·75	1·12
Vertical drilling machine boring a hole 4 inches diameter	·20	·30
Ditto ditto ditto 12 ditto	·38	·56
Milling machine, with cutters 8 inches diameter . .	·20	·30
Ditto ditto ditto 15 ditto . . .	·52	·77
Screwing machine, screwing iron-bolts 1 inch diameter .	—	·12
Wheel-cutting machine, cutting cast-iron wheels 1½ in. pitch	·39	·58
Horizontal boring machine, boring a hole 18 in. diameter	·44	·66
Cylinder boring machine, boring 4 feet diameter . .	·75	1·12
Punching and shearing machine for plates ⅝ inch thick .	—	1·16
Ditto ditto ditto 1 ditto .	—	2·45
Plate-bending-machine for plates 4 ft. wide and ⅜ in. thick	—	2·30
Ditto ditto ditto 10 ditto ⅝ ditto	—	4·48

The Horse-power in this Table is for ordinary Light Duty Machine Tools when working at ordinary Speeds, as given on pages 216 and 217.

Cisterns and Tanks.—The pressure of water is equal in all directions, and water will rise to the same level in all parts communicating with a vessel containing it, whatever be their shape and form.

The centre of pressure of a rectangle is at two-thirds the depth from the top.

The centre of pressure of a triangle whose base is horizontal, and upon the water line, is at one-half of the depth. The centre of pressure of a triangle whose summit is at the water-line, the base being horizontal and at the lower level, is at three-fourths of the depth.

The centre of pressure of the water in a cistern is at two-thirds of the depth of the water, measured from the surface of the water. The mean pressure of the water in a cistern is at one-half of the depth of the water.

The maximum pressure of water in lbs. on each of the sides and ends of a cistern is at the point of the centre of pressure, and it is =

Depth of the water in feet × ⅔ × 62·42 lbs. × the area in square feet of the wetted surface of the side or end of a cistern.

The mean pressure of water in lbs. on each of the sides and ends of a cistern is equal to one-half the pressure due to full depth, and it is =

Depth of water in feet × ·5 × 62·42 lbs. × the area in square feet of the wetted surface of the side or end of a cistern.

The pressure of water in lbs. on the bottom of a cistern is = the length in feet × the width in feet × the depth in feet × 62·42 lbs.

Take, for instance, a cistern 8 feet long, 5 feet wide, and 4½ feet deep, full of water. Then the maximum pressure, or that at the point of the centre of pressure, is = 4½ feet deep of water × ⅔ × 62·42 lbs. = 187·26 lbs. pressure per square foot of the surface of each of the sides and ends of the cistern. The total pressure on each side of the cistern, at the point of the centre of pressure, is = 8 feet × 4½ feet × 187·26 lbs. = 6,742 lbs. The total pressure on each end of the cistern, at the point of the centre of pressure, is = 5 feet × 4½ feet × 187·26 lbs. = 4,224 lbs.

The strength of the material of a cistern is governed by the mean pressure. The mean pressure on each of the sides and ends of this cistern is = 4·5 feet deep of water ÷ 2 × 62·42 lbs. = 140·5 lbs. per square foot of surface. The total pressure on each side of the cistern is = 8 feet × 4½ feet × 140·5 lbs. = 5,058 lbs., and that on each end of the cistern is = 5 feet × 4½ feet × 140·5 lbs. = 3,162 lbs. The pressure on the bottom of the cistern is = 8 feet × 5 feet × 4½ feet × 62·42 lbs. = 11,236 lbs.

Table 173.—CONTENTS OF CYLINDRICAL CISTERNS—STOCK SIZES.

Diameter in inches.	Height in inches.	Gallons (about).	Diameter in inches.	Height in inches.	Gallons (about).	Diameter in inches.	Height in inches.	Gallons (about).
14	21	10	23	35	50	30	54	140
18	24	20	25	36	60	36	60	225
19½	30	30	27	42	80	42	66	330
21	33	40	28	48	100	48	72	470

Table 174.—Galvanized Iron Cisterns—Stock Sizes.

Length.		Width.		Depth.		Gallons.
feet.	inch.	feet.	inch.	feet.	inch.	About.
1	9	1	3	1	6	20
2	0	1	6	1	7	30
2	4	1	7	1	9	40
2	6	1	7	2	0	50
2	8	1	10	2	0	60
2	8	2	0	2	2	70
3	0	2	0	2	2	80
3	2	2	2	2	2	90
3	0	2	2	2	6	100
3	4	2	4	2	6	120
3	6	2	6	2	6	140
3	6	2	6	2	9	150
3	9	2	8	2	10	175
4	0	2	8	3	0	200
4	1	3	3	3	0	250
4	7	3	6	3	0	300

Pumping Water.—Rules for pumps are given at pages 98—105. The following additional data may be useful:—Water is generally considered to be incompressible, but under a pressure of 65,000 lbs. per square inch, it is compressed 10 per cent., and alcohol more than 15 per cent.

The weight of one cubic inch of pure or fresh water, at a temperature of 65° Fahr. is ·03607 pound, and cubic inches multiplied by ·003607 = gallons; and gallons multiplied by ·16045 = cubic feet.

The capacity of a cylinder 1 inch diameter and 1 inch long is = 1 inch diameter^2 × ·7854 × 1 inch long = 7854 cubic inch; and ·7854 cubic inch × ·003607 = ·002832 gallon, and also = ·002832 × 10 = ·02832 pound; and ·002832 gallon × ·16045 = ·0004543 cubic foot.

The theoretical quantity of water delivered by a pump may be found with the above data by the following rules:—

Let D = the diameter in inches of the pump ram, or of the barrel of the pump, if it be fitted with a water-piston; S = the length of stroke of the pump in inches; N = the number of strokes per minute during which water is admitted to the pump.

The discharge of a pump in cubic inches per minute = $D^2 \times {\cdot}7854 \times S \times N$.

The discharge of a pump in cubic feet per minute = $D^2 \times S \times {\cdot}0004543 \times N$.

The discharge of a pump in pounds per minute = $D^2 \times S \times {\cdot}02832 \times N$.

The discharge of a pump in gallons per minute = $D^2 \times S \times {\cdot}002832 \times N$.

In pumping sea-water multiply the discharge found by these rules by 1·026.

Example—Required the quantity of water in gallons discharged by a pump having a ram 4½ inches diameter, and 6 inches stroke; water being admitted to the pump during 100 strokes per minute.

Then 4·5 inches diameter × 4·5 inches × 6 inches stroke × ·002832 ×

100 strokes per minute = 34·4 gallons of water discharged per minute, and = 34·4 × 60 = 2,064 gallons per hour.

These rules apply to both single-acting and double-acting pumps.

Flow of Water in Pipes.—Rules for the discharge of water from pipes are given at pages 97 and 116. The following are also useful rules:—

The velocity of water in feet per minute necessary for the discharge of a given quantity of water may be found by this rule:—

$$\frac{\text{Cubic feet of water discharged per minute} \times 144.}{\text{Sectional area of the pipe in square inches.}}$$

The following are common velocities for the flow of water in pipes for water-supply:—

Diameter of pipe in inches .	4	6	12	18	24	36	48
Velocity of flow of water in feet per second . . .	1½	1¾	2	2¼	2½	3	3¼

The sectional area of a pipe in square inches necessary for a given quantity and velocity of water may be found by this rule:—

$$\frac{\text{Cubic feet of water discharged per minute} \times 144.}{\text{Velocity of the water in feet per minute.}}$$

The diameter of the pipe in inches = $\sqrt[2]{(\text{area in square inches} \div {}\cdot 7854)}$.

The theoretical indicated horse-power required to raise water may be found by these rules:—

$$\frac{\text{Pounds of water raised per minute} \times \text{height of lift in feet}}{33{,}000.}$$

$$\frac{\text{Cubic feet of water raised per minute} \times \text{height of lift in feet}}{529.}$$

In practice it is necessary to make an addition to the theoretical power of from 25 to 50 per cent. to allow for the friction in working the pump.

The head required to produce a given velocity of water in a pipe may be found by the following rule from "Engineering," which is based on the fact that in the majority of cases the velocity of flow in a pipe is from 2 feet to 4 feet per second, the average being 3 feet per second. The head required to maintain a velocity of 3 feet per second through a length of clean cast-iron pipe is:—

$$\text{Head in feet} = \frac{\text{Length of pipe in feet}}{25 \times \text{diameter of pipe in inches.}}$$

The discharge in cubic feet per minute is very nearly equal to the square of the diameter of the pipe in inches, the error being under 2 per cent. in excess. For a velocity of 1 foot per second less than 3 feet per second, the head must be reduced one-half, and by a proportionate amount for intermediate cases. For a velocity of 1 foot per second more than 3 feet per second, the head must be increased by ·7 times that required for a velocity of 3 feet per second, and that required for intermediate cases may be determined by adding a proportionate amount for that required for the 1 foot per second increase in velocity.

Discharge of Sewage.—A gallon of water, and also of sewage, weighs 10 lbs.: one cubic foot weighs 62·42 lbs. = 6¼ gallons: one cwt. is = 1·8 cubic feet = 11·2 gallons. One inch in depth of sewage over an acre of land is equivalent to 101 tons, or 22,600 gallons. The average weight of the solid and fluid excreta of a human being is 2½ lbs. per day. The urine of 100,000 persons weighs 234,380 lbs., and the fœces of 100,000 persons weighs 15,620 lbs., the fœces, or solid portion, being to the fluid, or urine, as 1 to 16. For corrosion of metal by sewage, see page 340.

The diameter of a sewer may be found by the following formula from the "Engineer":—Multiply the quantity of water in cubic feet consumed per head of the inhabitants per day by the number of the inhabitants. This will give the total sewer discharge for 24 hours. Assume that one-half of this quantity will pass into the sewers in six hours, and calculate the number of cubic feet per second. To this must be added the rainfall. Assume that rain falls to a depth of ¼ inch in 24 hours over the whole area of the district, and calculate the number of cubic feet per second of rainfall Add this to the volume of sewage in cubic feet per second, and the sum is the total volume of liquid flowing into the sewer. Assume any size of sewer, say 2 feet in diameter. Calculate by the following formula the velocity of discharge, with the inclination of 1 in 630, or 8·38 feet per mile.

$$V = \cdot 92 \sqrt{2 f h y}.$$

In which V = the velocity in feet per second; f = the fall in feet per mile = 8·38; hy = the hydraulic mean depth = the area of the sewer divided by its circumference, which is = ·5 feet for a sewer 2 feet diameter.

Multiply the velocity obtained by this formula by the area of the sewer, = 3·141 square feet in this case, and if the product is more or less than the total volume of sewage and rainfall, a smaller or larger size of sewer must be assumed and the calculation repeated.

The following rule gives the flow of sewage:

$$V = \frac{188 \, r \sqrt{s}}{\cdot 64 + \sqrt{r}}.$$

In which V = the velocity in feet per second; r = the hydraulic radius, = area of section ÷ wetted perimeter; s = the slope of the fluid surface.

This formula is applicable to all varieties of sewer with a maximum error in this class of work of 5 per cent., which is always on the safe side. If greater accuracy is required the following formula may be used:—

$$V = (A \, r \sqrt{s}) \div (B + \sqrt{r}).$$

In which A and B are constants depending on the character of the surface of the sewers, and their values for different cases are as follows:—

Different Degrees of Roughness.	A	B
Surface very smooth, with even joints . .	213	·54
Surface very good	200	·59
Surface of average smoothness	188	·64
Surface rougher	178	·69
Surface of bad brickwork with washed-out joints.	169	·73

QUALITIES OF METALS.

Gold of fine or pure quality is nearly as soft as lead. To enable it to resist wear, it is hardened by alloying with copper and silver. The fineness of gold is denoted by the number of carats present in 24 carats of the alloy, pure gold being 24 carats fine; standard or sovereign gold is 22 carats fine, and is a mixture of 22 parts gold and 2 parts copper. A new sovereign weighs 123·27447 grains, or a little more than 123¼ grains, and when its weight is reduced by wear to under 122½ grains it is not a legal tender. A new half-sovereign weighs 61·63723 grains, and when its weight is reduced by wear to under 61·125 grains, it is not a legal tender. After a sovereign has been in circulation for 20 years, its weight will have been reduced by wear to a little below the minimum legal weight. The gold coinage of this country weighs about 800 tons. The gold used for the best class of jewellery is 18 carats fine, and is a mixture of 18 parts gold and 6 parts copper. The gold used for common jewellery is 9 carats fine and is a mixture of 9 parts gold and 15 parts copper. Jewellers test gold with nitric acid, which leaves a stain on metal which is much alloyed, the colour of the stain varying according to the quality of the metal. Nitric acid does not affect 18 carat gold, but produces a dark stain on 9 carat gold, and a green stain upon the metal when a large proportion of copper, brass, or German silver is present. Gold dissolves in aqua regia or a mixture of one part nitric acid and four parts hydrochloric acid.

Silver of fine or pure quality is soft and ductile; its power of conducting electricity and heat is superior to all other metals. Standard silver used for coins, is a mixture of 92½ parts silver and 7½ parts copper, 1 lb. of which contains 11 oz. 2 dwts. silver and 18 dwts. copper. The fineness of silver is denoted by the number of dwts. it is better or worse in quality than standard silver. Nitric acid produces a black mark on fine silver, and a green mark on silver which is much alloyed.

Copper being more malleable than ductile, is more suitable for being hammered and rolled into plates, than being drawn into wire; its malleability and ductility depend greatly upon its purity. Copper, during the process of being hammered, rolled, or drawn into wire, becomes hard, stiff, and liable to crack, and requires to be frequently annealed to restore it to its normal quality; when these processes are carefully carried out, the strength of copper is thereby considerably increased. Bean-shot copper is obtained by pouring melted copper into hot water, and feathered-shot copper by pouring melted copper into cold water. The bronze coinage of this country and of France is a mixture of 95 parts copper, 4 parts tin, and 1 part zinc. One farthing weighs ⅒ oz., 1 halfpenny ⅕ oz., and 1 penny ⅓ oz.

Tin possesses very little tenacity, but is very malleable, and may be beaten and rolled into thin leaves of tin-foil of the one-thousandth part of an inch in thickness; when quickly bent tin gives a creaking sound. Tin is not much affected by weak acids, or by exposure to the air. Tin-plate is sheet-iron coated with tin. Tin-salt is obtained by dissolving tin in hydrochloric acid. Tin is dissolved by mercury, and an amalgam of tin and mercury is used for silvering mirrors. Grain-tin is made by heating tin of very pure quality to nearly the melting point—when it becomes brittle—and dropping it from a height, which breaks it into prismatic pieces. The quality of tin may be tested by casting it in a stone mould, and when it is cold, the impure tin will be frosted all over, the common tin partly frosted, and the refined tin will be smooth and bright.

Zinc is brittle both at ordinary and at high temperatures, but is malleable at a temperature of 250° F., when it may be rolled into sheets or drawn into moderately fine wire. Zinc is very little affected by exposure to the air. A coating of zinc on iron prevents its oxidation. The addition of 10 per cent. of bismuth makes it more easily melted, and the addition of 10 per cent. of chloride of ammonium is said to increase its hardness.

Lead is very malleable but is not tenacious, and cannot be drawn into very fine wire; it resists the action of muriatic, sulphuric, and other acids, strong nitric acid does not affect it much, but diluted nitric acid soon dissolves it. The addition of a little lead makes brass more ductile, but a large addition makes it brittle, and causes the metals to separate during solidification. The addition of a little resin to lead just before pouring, prevents the metal scattering, when being poured round a damp joint.

Antimony is a very brittle and a comparatively light metal, it is used principally for alloying with other metals, to harden tin and lead in making white-metal for bearings, &c., type-metal, and stereotype metal. It melts at 810° F.

Bismuth is a very brittle, reddish-white crystalline metal. It is used principally for imparting fusibility to other metals. It possesses the property of expanding considerably during solidification, and is useful for taking impressions of dies. It melts at 507° F.

Cadmium is a silver-white crystalline metal, similiar in appearance to tin, but harder and more tenacious. It is malleable and ductile at the ordinary temperature, but is brittle at 185° F. It melts at the low temperature of 442° F., but it is difficult to use as an ingredient of alloys, because it volatilises rapidly at the ordinary temperatures necessary for making alloys. It is dissolved easily by mineral acids.

Nickel is a white metal that takes a high silver-like polish. In its commercially pure state, it is slightly stronger and harder than pure iron, and it is much less easily oxidised by moisture. It also resists the action of alkalies. It absorbs oxygen when melted, and requires the addition of about ·1 per cent. of magnesium, in order to form a sound casting. It may be heated to redness without perceptible oxidation, is slowly soluble in hydrochloric and sulphuric acid, and is readily soluble in dilute, but remains passive in concentrated nitric acid. The tensile strength of cast nickel is from 18 to 20 tons per square inch, with from 9 to 18 per cent. elongation, and a granular fracture, and when forged and rolled from 30 to 32 tons per square inch, with from 44 to 54 per cent. elongation, and a silky fracture.

Aluminium is a brittle metal unless annealed. When annealed it is very much like copper in softness, malleability, toughness, and silky fibrous fracture. It may be rolled into sheets of two-thousand parts of an inch in thickness. The elasticity of annealed aluminium is very slight, but when hard rolled or drawn, without being alternately annealed, it has considerable elasticity, especially when alloyed. Pure aluminium is less affected by dry and damp air at ordinary temperatures than any other metal, except gold and platinum. Water does not act on it, either at the ordinary temperature or at the boiling point, even when at a red heat, and super-heated steam has scarcely any appreciable effect. Sea-water has also very little effect on it. Diluted sulphuric acid, in which iron and zinc are quickly dissolved, acts only very slowly on aluminium; and nitric acid which dissolves or oxidises all metals except gold and platinum, does not affect pure aluminium. The best solvents for aluminium are muriatic (hydrochloric) acid and caustic soda, or potash solutions.

Cast-Iron is made from iron-ore, placed in alternate layers with coal or coke mixed with limestone, in a blast-furnace supplied with forced blast to assist the combustion of the fuel. The melted ore is cast in moulds, and forms pig-iron. When the iron is rapidly cooled, a white crystalline metal is produced, called white-iron. When cooled slowly, the metal has a grey or mottled fracture. White iron melts more easily than grey iron. The heavier the metal, the stronger it generally is. Cast-iron generally contains from 2 to 5 per cent. of carbon, its essential constituent. The strength of cast-iron varies according to the distribution and massiveness of the metal. Thicker pieces are less strong than thinner pieces; an inequality which arises from the fact that the outer portions, at and near the surface of a casting, are denser, harder, and stronger than the central portions. The compressive strength of cast-iron is generally from four to seven times as great as its tensile strength. Cast-iron of average quality loses strength when heated above 120° Fahr., and it becomes insecure at the freezing-point. At a red heat, its normal strength is reduced one-half. Cast-iron generally resists the action of sea-water better than wrought-iron. For the different brands of cast-iron see page 240.

Malleable Cast-Iron is fine, close-grained, cast-iron, rendered malleable by the extraction of part of the constituent carbon, according to the method described on page 265.

Wrought-Iron is made from pig-iron, melted in a reverberatory furnace. Air is forced into the molten metal by tuyeres, and a white iron is produced, which is puddled and worked into balls or blooms. In order to squeeze out the slag and impurities, the blooms are worked under a steam-hammer. Good wrought-iron contains little or no carbon, and it is a nearly pure iron. The compressive strength of wrought-iron is generally only about one-half as great as its tensile strength. Wrought-iron resists the action of sea-water better than steel.

Steel is a compound of iron with from 0·5 to 1·5 per cent. of its weight of carbon, the more carbon it contains the harder the steel is. The quality of steel depends upon the purity of the materials, the quality of the workmanship, and the care taken in its production.

Bessemer Steel is made from pig iron, by passing a strong blast of air through the molten metal, which removes the carbon and purifies the metal, the residue being malleable iron in a melted state; a small quantity of spiegel-eisen is afterwards run into the vessel. The steel thus produced is run into ingots, which are hammered and rolled like blooms of wrought-iron

Blister-Steel is made by a similar process to case-hardening, called cementation. A number of bars of best wrought-iron are embedded in layers of charcoal—contained in a trough—and are subjected to a temperature of about 2000° F. in a suitable furnace for 4 days for spring steel, 8 days for shear steel, and 12 days for chisel steel. Each bar absorbs carbon, and is converted into steel at the surface, and into steely iron at the interior of the bar.

Cast Steel is manufactured by melting short pieces of blister-steel i a crucible together with carbon and manganese.

Shear Steel. Short bars of blister-steel are tied in bundles to form a fagot, which is heated and welded with a quick speed tilt-hammer, and afterwards re-heated and hammered into a bar. To make double shear steel, the bar is broken in two and the pieces are welded together.

Homogeneous Metal is made by melting small pieces of best wrought-iron in a crucible with the proper quantity of carbon, some spiegel-eisen being added when the operation of melting is nearly completed.

Siemens Steel is a mild steel made from pig-iron in a furnace heated by gas. The iron is melted with hematite, and ferro-manganese is afterwards added. Siemens-Martin Steel is mild steel, made from pig-iron and steel-scrap. In some tests of Siemens Steel the breaking loads were from 25 to 28½ tons per square inch, with from 28 to 37½ per cent. elongation.

Manganese Steel is a very strong and ductile steel, containing from 7 to 20 per cent. of manganese. Its tensile strength is about double that of ordinary mild steel. It makes good and sound castings, and has great wear-resisting properties. In some tests of manganese steel the breaking loads were from 57 to 65 tons per square inch, with from 40 to 50 per cent. elongation.

Nickel Steel is distinguished from ordinary mild steel by its high elastic strength. The elastic limit of mild carbon steel is from 40 to 50 per cent. of its tensile strength. The addition of nickel to soft steel and homogeneous iron, considerably increases its ductility, and also the proportion of its elastic limit to tensile strength. The elastic limit of nickel steel is from 55 to 80 per cent. of its tensile strength, according to the percentage of contained nickel. In a general way, nickel steel is from 10 to 50 per cent. greater in elastic limit, and from 30 to 50 per cent. greater in tensile strength than steel of the same composition without nickel. When annealing nickel steel, it should not be heated above cherry-red.

Table 175.—STRENGTH OF MILD CARBON STEEL AND NICKEL STEEL.

Purpose it is Suitable for.	Constituent Carbon.	Mild Carbon Steel.			Nickel Steel, containing from 3 to 3½ per Cent. of Nickel.		
		Tensile Strength in Tons per Square Inch.	Elastic Strength in Tons per Square Inch.	Elongation per Cent.	Tensile Strength in Tons per Square Inch.	Elastic Strength in Tons per Square Inch.	Elongation per Cent.
Stay-bolts and studs .	·15—·18	25	11½	25	34	20	25
Fire-box plates . . .	·15—·20	26	12	25	35	21	25
Boiler plates . . .	·15—·23	27	12½	25	36	22	25
Connecting rods . .	·20—·25	28	13	25	37	23	25
Shafting and axles .	·25—·30	34	16	22	46	28	22
Piston rods	·30—·35	37	17	20	50	30	20
Crank-pins	·35—·40	40	18	18	55	33	18
Forgings	·45—·50	45	20	15	60	36	15

The nickel steel in the above Table is slightly less liable to corrosion than the mild carbon steel. With steel containing the same quantity of carbon, liability to corrosion decreases as the constituent nickel increases.

Whitworth's Compressed Steel is ordinary steel, compressed while fluid under a pressure of from 4 to 12 tons per square inch, whereby it gains in solidity and strength. The elastic limit of steel may be considerably increased by compression.

The Hardness of Metals varies according to their purity. The hardness of a number of metals is given in the following Table :—

Table 176.—COMPARATIVE HARDNESS OF DIFFERENT METALS.

Description.	Comparative Hardness. Hardened Tool Steel = 1,000.	Description.	Comparative Hardness. Hardened Tool Steel = 1,000.
Hardened tool steel . .	1,000	Palladium	200
Rhodium and Iridium . .	600	Platinum and Soft bronze	180
Hard cold-blast cast-iron	500	Copper	150
Manganese and Cobalt .	490	Aluminium	140
Chisel steel, containing 1 per cent. of carbon .	480	White metal plate . . .	120
Steel forgings, containing ·5 per cent. of carbon .	470	Silver	100
Nickel	465	Zinc	90
Mild steel, containing ·17 per cent. of carbon	460	Gold	80
Wrought-iron, ordinary .	450	Thallium	70
Bronze bearing metal . .	430	Soft brass	60
Light grey cast-iron . .	420	Cadmium	50
Hard brass	300	Magnesium	40
		Bismuth	30
		Tin	15
		Lead	8

The quality of Iron and Steel may be ascertained by immersing a small well-polished piece in diluted nitric acid for 12 hours, when its structure will be exposed by the action of the acid, and best steel will appear frosted; common steel honeycombed; best wrought-iron will show fine fibres; common wrought-iron, coarse fibres; and grey cast-iron will show well defined crystals of carbon.

Corrodibility of Metals.—The relative liability of metals to rust, when in contact with water of different kinds, in comparison with cast-iron under the same conditions, is approximately as follows:—

	Hard Water.	Soft Water.	Sea-Water.	Slightly Acid Water.	Sewage Water.
Cast-iron . . .	100	100	100	100	100
Wrought-iron .	125	135	140	145	150
Mild-steel . .	130	140	145	150	155
Cast-steel . . .	135	145	150	155	160

Water from hills and moors is generally softer, and of a more corrosive nature, than water from wells.

Prevention of Corrosion.—Red-lead paint, composed of 88 per cent. of red lead and 12 per cent. of raw linseed oil, is the most efficient of all paints in protecting iron from rust. Paints vary considerably in efficiency. Rusting goes on to a greater or less extent under all paints. The useful life of paint on metal in the open air is three years.

With well applied good paint, the reduction produced by rust in the weight of iron after being painted 5 years is approximately as follows:—

	Per Cent.		Per Cent.		Per Cent.
Red-lead paint . .	½	Zinc-white paint .	1	Brown paint . . .	2
Red-oxide paint . .	⅝	White-lead paint .	1¼	Black paint	4
Orange-lead paint .	¾	Barytes paint . .	1½	Green paint . . .	5

Iron should be clean and free from rust before painting; and old paint should be removed before re-painting. Recipes for the removal of paint are given elsewhere, but a more rapidly effective composition consists of 1 lb. of lime, 4 lbs. of powdered potash, and 1½ gallons of water.

Tar is a good rust-preventative. Cast-iron pipes for water supply are protected from rust by being heated in a brickwork stove to about 600° Fahr. and then dipped vertically into a boiling tar-composition. The pipes remain in the composition until they are of the same temperature, when they are withdrawn and cooled in a vertical position. Dr. Angus Smith's composition for this purpose, consists of one part of tar, and three parts of pitch-oil. Another composition consists of 95 per cent. of coal-tar-pitch, and 6 per cent. of linseed oil, a little resin being sometimes added. The pipes should be free from rust when dipped. Pipes properly treated in this manner may remain free from rust for a period of from 5 to 7 years.

Barf's process for protecting iron from rust, consists of a coat of magnetic oxide of iron, produced by passing either superheated steam, or fuel-gas, over the iron when red hot.

Table 177.—List of Woods and their Uses.

The Letter H. means Hard; M., Medium, and S., Soft.

Acacia, H., fencing, turnery.
Alder, H., sluices, pumps.
Almond, H., tool handles.
Apple, M., turnery.
Ash, H., wagons, implements.
Beech, H., planes, boot lasts.
Birch, H., furniture.
Boxwood, H., engraver's blocks.
Cedar, S., pencils, cigar boxes.
Cherry, European, S., Tunbridge ware, fancy work.
Cherry, Australasian, H., gun stocks, cabinet work.
Ebony, H., rulers, cabinet work.
Elder, S., rules, shuttles.
Elm, H., piles, pumps, pipes.
Fir, S. carpentry.
Hawthorn, H., turnery.
Hickory, H., vehicles, wheel spokes.
Holly, H., turnery.
Hornbeam, H., teeth of wheels.
Horsechestnut, S., brushes, turnery.
Ironwood, H., teeth of wheels.
Laburnum, H., turnery.
Lancewood, H., fishing rods, bows.
Larch, S., carpentry.
Laurel, H., turnery.
Lignum Vitæ, H., pestles, turnery.
Lime, close grained, carving.
Mahogany, H., furniture.
Maple, M., furniture.
Mountain Ash, H., cart shafts.
Nettle Tree, H., flutes.
Oak, H., shipbuilding, &c.
Olive, M., turnery, boxes.
Partridge, H., walking sticks.
Pine, S., carpentry.
Poplar, M., furniture, turnery.
Rosewood, H., pianos, furniture.
Sandal Wood, S., fragrant, fancy boxes, cabinet work.
Sassafras, H., turnery, screws.
Silver Wood, beautifully marked, cabinet work, fancy boxes.
Snake Wood, nicely marked, walking sticks.
Sycamore, S., turnery, furniture.
Teak, H., buffer beams.
Thorn, H., turnery.
Tulip Wood, H., veneers, cabinet work, fancy work.
Walnut, H., furniture, gun stocks.
Whitewood, H., wood engravers' blocks, cabinet work.
Willow, S., baskets, spoons, &c.
Yew, H., walking sticks, turnery.
Zebrawood, M., brushes, cabinet work.

The most beautifully marked woods are rosewood, Italian walnut, Virginia walnut, Spanish mahogany, bird's eye maple, satin-wood, tulip-wood, snake-wood, silver-wood, laburnum, olive-wood, lemon-wood, yew, oak, pitch-pine, and coromandel-wood.

The most even and close-grained woods are ebony, myrtle, lime, box, olive, Virginia walnut, pear-tree, sycamore, cowrie-wood, beech, pine and holly.

The most durable woods are oak, ebony, cedar, box, hornbeam, poplar, larch, chestnut, lignum vitæ, teak, elm, acacia, and yellow deal.

The most elastic woods are lancewood, hickory, ash, hazel, snake-wood, yew and chestnut.

The scented woods are sandal-wood, sassafras, camphor-wood, cedar, rosewood and satin-wood.

The dye-woods are logwood, saunders-wood, Brazil-wood, cane-wood, fustic, zante and green ebony.

Qualities of Timber.—The most odoriferous kinds of woods are generally esteemed the most durable; also woods of a close and compact texture are generally more durable than those that are open and porous. In general, the quantity of charcoal afforded by woods offers a tolerably accurate indication of their durability; those most abundant in charcoal and earthy matter are most permanent; and those which contain the largest proportion of gaseous elements are the most destructible. The chestnut and the oak are pre-eminent as to durability, and the chestnut affords rather more carbonaceous matter than the oak. But this is not always the case, as red or yellow fir is as durable as the oak in many situations. An experiment to determine the comparative durability of different woods was made with planks of trees 1½ inches thick of from thirty to forty-five years' growth; after standing ten years in the weather, they were examined and found to be in the following state:—*

Cedar, perfectly sound.
Larch, the heart sound but sap quite decayed.
Spruce fir, sound.
Silver fir, in decay.
Scotch fir, much decayed.
Pinaster, quite rotten.
Chestnut, perfectly sound.
Abele, or great white poplar, sound.
Beech, sound.
Walnut, in decay.
Sycamore, much decayed.
Birch, quite rotten.

This shows the kinds of woods best adapted to resist the weather, but even in the same kind of wood there is much difference in the durability; the timber of those trees which grow in moist and shady places is not so good as that which comes from a more exposed situation, nor is it so close, substantial, and durable.

The best Oak Timber when new is of a pale brownish-yellow colour, with a faint shade of green, a glossy and firm surface. The more compact it is and the smaller the pores are the longer it will last; but the open, porous, and foxy-coloured oak is weak and not durable. Oak contains gallic acid which corrodes iron, therefore it should be fastened with either galvanised iron or copper screws. Oak shrinks about one thirty-second part of its width in seasoning, and warps and twists much in drying.

Alder is extremely durable in water or wet ground, and is valuable for piles, pumps and sluices, and for any purpose where it is constantly wet, but it soon rots when it is exposed to the weather or to damp, and in a dry state it is much subject to worms.

Elm is extremely durable in water and makes excellent piles and planking for wet foundations, and is used also for making pumps, keels of ships, &c. Old London Bridge stood upon piles of elm, which remained six centuries without material decay.

Beech is durable when constantly immersed in water and is useful for piles in situations where it will be constantly wet, but it rots quickly in damp places and is soon injured by worms.

* See Carpentry and Joinery." The Technical Press Ltd.

Ash is durable in a dry situation, but soon rots when exposed to either damp or alternate dryness and moisture. Ash is superior to any other British timber for toughness and elasticity.

The strength of timber to resist breaking strains in tension and compressure is given at pages 345 and 390. The tenacity along the grain is greatest in those woods which have the straightest and most distinctly marked fibres. The tenacity across the grain is about $\frac{1}{7}$ in pine-wood, and $\frac{1}{16}$ in leaf-wood of the tenacity along the grain.

The resistance to crushing along the grain depends upon the resistance of the fibres to being split asunder. It averages from 50 to 70 per cent. of the tenacity for dry timber, and half that per-centage for green timber. The resistance to crushing across the grain is considerably less than the resistance to crushing along the grain, in all woods excepting lignum-vitæ, which resists a crushing force with nearly equal strength along and across the grain. Ebony, iron-wood, and box-wood also offer considerable resistance to crushing across the grain.

The toughest wood is that which bears the greatest load and bends the most at the time of fracture. The following list shows the comparative toughness of various kinds of timber. Ash being 1·00; beech is ·85; cedar of Lebanon, ·84; larch, ·83; sycamore and common walnut, each ·68; occidental plane, ·66; oak, hornbeam, alder, and Spanish mahogany, each ·62; teak and acacia, each ·58; elm and young chestnut, each ·52.

Trees should not be cut down before they arrive at maturity. If cut down before maturity a great part of the tree is sap-wood and the heart-wood is deficient in strength and durability; if allowed to grow beyond maturity the wood is brittle, discoloured, devoid of elasticity, and soon decays. An oak tree arrives at maturity at 100 years of age; the average quantity of timber produced by a tree of that age is about 75 cubic feet; and it should not be felled at a less age than 60 years. Poplars should be cut down when the trees are between 30 and 50 years old; ash, larch, and elm between 50 and 100 years old, and the Norway spruce and Scotch pine between 70 and 100 years old.

Measuring Timber.—*To find the Solidity of Round or Unsquared Timber.—Rule:* Multiply the square of ¼ of the circumference—or quarter girth—by the length, and the product will be the content.

If the tree tapers regularly the girth must be taken in the middle of the tree. When the taper is not regular several girths must be taken, and their sum divided by their number will give the mean girth, which must be used in the above rule. An allowance for the bark, of from ½ inch to ¾ inch for every foot of the quarter girth for ash, elm, beech, and young oak, and of from 1 inch to 2 inches for old oak, is usually deducted from the ¼ girth.

To find the Solidity of Squared or Four-sided Timber.—Rule: Multiply the mean breadth by the mean thickness, and multiply the product by the length.

WORKSHOP RECEIPTS.

Composition for Taking Impressions and Casts.—4 parts black resin; 1 part yellow wax.

Flexible Composition for Taking Impressions and Casts.—Glue, 12 parts; melt and add treacle, 3 parts.

Modelling Clay.—Knead dry clay with glycerine.

Modelling Wax.—Equal parts of beeswax, lead plaster, olive oil, and yellow resin; add whiting enough to make a paste.

Flux for Brass.—1 oz. common soap; ½ oz. quicklime; ¼ oz. saltpetre; mix into a ball, and place in the crucible when lifted out of the furnace. This is sufficient for about 50 lbs. of metal.

Dusting for Moulds for Brass Work.—To produce castings with a clean face and fine skin: for light castings of brass and gun metal, after moulding, first dust the moulds with pea-meal, and on the top of same add a slight dust of plumbago. For heavy gun metal castings, dust only with plumbago.

Plumbago Crucibles are made of 2 parts graphite and 1 part fire clay.

Fire-clay Crucibles.—2 parts Stourbridge clay; 1 part finely powdered hard gas coke.

Berlin Crucibles.—8 parts Stourbridge clay; 3 old crucibles ground finely; 5 coke; 4 graphite.

To Prevent Castings Shaking after being Cast on to Wrought Iron.—Split the end of the wrought iron bar, and well jag the same.

To Remove Sand and Scale from Small Castings of Iron.—Pickle for 14 hours in a solution of water, 4 parts; oil of vitriol, 1 part.

To Clean the Surface of Copper.—Scour with muriatic acid and fine sand, and rinse with water.

To Clean Tarnished Bronze and Brass Work.—Rub with a paste made of oxalic acid, 1 oz.; rottenstone, 6 oz.; powdered gum arabic, ½ oz.; sweet oil, 1 oz.; water sufficient to make a paste; rinse with water, and finish with whiting and leather. A golden colour may be given to clean brass by first pickling it, and dipping for a few seconds in a solution of water, muriatic acid, and alum.

To Clean Silver.—Apply the following solution with a soft brush:—cyanide of potassium, 4 drachms; nitrate of silver, 10 grains; water, 4 oz.; afterwards wash well with water, dry, and polish with soft wash leather.

To Clean Silver.—Another method is to brush it, with a solution of water, and hyposulphate of soda.

Polishing Brass Work in a Lathe.—Use old burnt crucibles, reduced to a fine powder.

In Turning Very Hard Iron or Steel use a drip for the tool, of petroleum, 2 parts; turpentine, 1 part; and add a little camphor.

Water Tests.—To ascertain if water is hard, put a few drops of soap dissolved in alcohol into a glass of water; if the water is hard, it will become milky. To ascertain if water contains iron, put a small piece of prussiate of potash into a glass of water; if the water contains iron, it will become a blue colour.

To Remove Nuts which have Rusted Fast on Bolts.—Make a funnel of clay round the nut, and fill it with petroleum, and let it remain for a few hours.

To Prevent Lamp Glasses from Breaking.—Anneal, by placing the glass in cold water, with some common salt added; raise to a boiling heat, gently. Boil for 20 minutes, and allow to cool slowly; the glass not to be removed until the water is quite cold.

Self-Lubricating Bearings.—In hard gun metal bushes,—bored and fitted to the shaft to bear properly all over,—drill 4 holes per superficial inch, each ¼ inch diameter × ¼ inch deep. The holes to be flat at the bottom, and to be spaced in zigzag rows, so that the holes in one row divide the spaces between the holes in the other row—and fill the holes with the following compound, viz.:—Melt 1 lb. solid paraffin, and add a small quantity each of litharge, dissolved isinglass, and sulphur; and then add 2 lb. fine plumbago, and mix thoroughly.

Antifriction Lubricating Compound for the Bearings of Engines and Shafting, and for Cylinders.—Lubricating paraffin oil, 1 gallon; solid paraffin, 2 lb.; plumbago, finest, 2 lb.; melt and mix thoroughly.

Axle Grease.—Tallow, 8 lb.; palm oil, 1 gallon; mineral oil, 1 gallon; plumbago, 1 lb.; melt and mix.

Axle Grease.—Water, 1 gallon; mineral oil, 1 gallon; tallow, 4 lbs.; palm oil, 6 lb.; soda, ½ lb.; melt and mix.

Grease for Wood Toothed Wheels.—Make a thin mixture of soft soap, and plumbago.

Machinery Oil.—A good oil for machinery consists of a mixture of good mineral oil, 15 gallons; rape oil, 6 gallons; lard oil, 4 gallons.

To Preserve Steel Instruments from Rust.—Rub the steel with vaseline. Another receipt for the same purpose is:—Mix equal parts of olive oil and carbolic acid. Another receipt is:—Camphor, ½ oz., dissolved in ½ pint olive oil. Another receipt is:—½ pint fat oil varnish, mixed with 2½ pints rectified spirits of turpentine.

To Preserve Metals from Rust use one of the following methods:—(1.) Cover with a mixture of white lead and tallow. (2.) Mixture of equal parts beeswax and ozokerit, melted together. (3.) Camphor, ½ oz., dissolved in 1 lb. of melted lard; take off the scum and mix in as much black lead as will give it an iron colour. Coat with this mixture, and let it remain on for 24 hours; then wipe off with a linen cloth;—or a better result will be got by leaving it on, if the articles are exposed to much damp. (4.) Coat with a mixture of paraffin oil, solid paraffin, and black lead. Vaseline may be effectively used for all metals.

To Refine Oil for Fine Mechanism.—Add equal parts of lead and zinc shavings to best olive oil, and leave it in a cool place until the oil becomes colourless.

Waterproofing Canvas.—Water, 1½ pint; hard yellow soap, 6 oz.; when boiling, add 5 lb. boiled linseed oil and ½ lb. patent dryers. Another method is to steep the canvas first in a solution of water, with 20 per cent. of soap, and afterwards into a solution containing 20 per cent. sulphate of copper.

Waterproofing Calico.—Boiled linseed oil, 1 quart; soft soap, 1 oz.; beeswax, 1 oz.; the whole to be boiled down to three-fourths of its previous quantity. Another method is—hard yellow soap, 4 oz., cut into shavings, and beat with sufficient water to the consistency of cream; then stir it well into 1 pint boiled linseed oil. Apply with a brush on one side of the calico only.

Tarpaulin Dressing for Waterproofing Sheets for Railway Wagons and Carts, &c.—Linseed oil, 95 gallons; litharge, 8 lbs.; umber, 7 lb.; boil for 24 hours, and colour with vegetable black, 8 lbs.

Waterproofing Brick Walls.—Soft paraffin wax, 2 lb.; shellac, ½ lb.; powdered resin, ½ lb.; benzoline spirit, 2 quarts; dissolve by gentle heat in a water bath; then add 1 gallon benzoline spirit; and apply warm. Being very inflammable, keep it away from fire.

Waterproofing Woollen Cloth.—Mix ½ lb. alum and ½ lb. sugar of lead in 2 gallons of rain water; stir up repeatedly at intervals during 3 hours; then allow to settle, and pour off the clear solution, in which immerse the cloth for 24 hours; after which let the cloth drip and dry, without wringing. Another method is to dissolve equal parts of isinglass, alum, and soap in water; each to be dissolved separately, and then all well mixed together; brush the solution on the wrong side of the cloth, and dry; afterwards brush the cloth well first with a dry brush, and then brush lightly with a brush dipped in rain water, and dry. Another process is:—boil the cloth in a solution of water, 1 gallon; soap, 2 oz.; glue, 4 oz., for several hours; afterwards wring and dry; and then steep for 10 hours in a solution of water, 1 gallon; alum, 13 oz.; salt. 15 oz.; wring and dry at 80° temperature.

Waterproofing Packing Paper.—First dissolve 1¼ lb. of white soap in 1 quart water; next dissolve 2 oz. of gum arabic and 5 oz. glue in a quart of water; mix the two solutions and heat; soak the paper in the mixture and hang up to dry.

Waterproof Dressing for Leather.—Beeswax, 1 oz.; powdered resin, 1 oz.; soap, 3 oz.; castor oil, 1 pint; boiled oil, 1 quart; boil, and afterwards thin to proper consistency with warm oil of turpentine.

Mixture for Preserving Leather Belts.—First wash the belt with warm water, and apply a mixture of castor oil, 2 quarts; tallow, 1 lb.; powdered resin, 1 oz.; hard soap, 2 oz.; melt and mix.

Dubbing.—Black resin, 2 lbs.; tallow, 1 lb.; train oil, 1 gallon.

Freezing Mixtures.

Sulphate of soda	8	parts by weight.
Hydrochloric acid	5	"
Pounded ice or snow	2	"
Common salt	1	"
Sulphate of soda	3	"
Dilute nitric acid	2	"
Sulphate of soda	6	"
Nitrate of ammonia	5	"
Dilute nitric acid	4	"
Phosphate of soda	9	"
Dilute nitric acid	4	"

Razor Paste.—Mix equal parts of jewellers' rouge, blacklead, and suet. Another receipt for the same purpose is—Levigated oxide of tin or putty powder, 1 oz.; powdered oxalic acid, ¼ oz.; gum, 20 grains.

Non-conducting Material for Clothing Steam Cylinders and Pipes, to prevent Condensation.—Silicate cotton.

To Harden the Surface of Wood Pulleys.—Boil them for 10 minutes in olive oil, and allow them to dry.

To Clean and Whiten Marble.—Make a paste of equal parts, whiting, pearlash, and dry soap; cover the article thickly, and allow the paste to remain on for 14 days; then wash off with a sponge and water.

Imitation Beeswax.—Melt and mix, solid paraffin, 60 parts; yellow resin, 40 parts.

Ink for Marking Packages.—Boil 2 oz. shellac and 2 oz. borax in 1½ pints of water until they are dissolved; then add 2 oz. gum arabic; when cold, add lamp black or Venetian red to the proper colour. Keep the ink in a bottle.

To Resharpen Files.—Old files worn too thin to recut, may be resharpened thus:—Clean the file by immersion, first in spirits of turpentine, and next in clean warm water; then place the cleansed file point downwards in a jar containing a solution of—nitric acid, 1 pint; sulphuric acid, 1 pint; water, 1 quart; and allow the file to remain in the solution, for an hour or more, according to the depth of teeth.

To make Small Artificial Stone Articles.—Reduce the stone to very fine powder, and mix it with as much fine soapstone as will make a thick dough; place the dough in a mould, and subject the same to a good pressure; after leaving the mould, bake the article in an oven.

Steam Joints made with Indiarubber.—Where indiarubber is used to make a steam joint—such as the joint of a mud-hole door—the indiarubber, as well as the faces of the joint, should be covered with a mixture of—tallow, 1 part; blacklead, 2 parts; which greatly adds to the efficiency and durability of the joint.

To Take the Sulphur out of Coke.—Water it with salt and water.

CEMENTS FOR THE LABORATORY AND WORKSHOP.

Acid-proof Cement.—Mix a concentrated solution of silicate of soda, with powdered glass to form a paste. ·

Aquarium Cement.—Mix white lead, red lead, and boiled oil together, with gold size to the consistency of putty. If required to be dark in colour, mix lamp black with it.

Another Aquarium Cement.—1 gill, litharge; 1 gill, plaster of paris; 1 gill, fine dry white sand; and ⅓rd gill each of powdered resin and red lead; mix into a stiff putty with boiled oil, to which a little gold size has been added.

Waterproof Cement.—Powdered resin, 1 oz., dissolved in 10 oz. strong ammonia.

China and Earthenware Cement.—Dilute white of egg with its bulk of water; mix to the consistency of paste with powdered quicklime.

China and Earthenware Cement.—Dissolve isinglass in hot water, and add acetic acid.

Another China Cement.—Finelv powdered glass, mixed with white of egg.

Office Paste.—Strong, and does not soon turn sour: ½ oz. alum, dissolved in 1 pint of water; add flour, and when boiled, add ¼ oz. resin, and again boil until properly dissolved and mixed.

Electric Cement for fastening Brass Work to Glass Tubes.—Resin, 5 oz.; beeswax, 1 oz.; red ochre or Venetian red in powder, 1 oz.

Fire-proof Cement.—Linseed oil, 4 oz.; handful of quicklime powdered; boil till thick and cool and harden; then dissolve and use in the same way as ordinary cement.

Elastic Glue.—Dissolve glue in a water bath; evaporate to a thick fluid, and add an equal weight of glycerine; cool on a slab.

Liquid Glue.—White glue, 16 oz.; dry white lead, 4 oz.; soft water, 2 pints; alcohol, 4 oz.; stir and bottle while hot.

Another Liquid Glue.—Glue, 3 pints, softened in 8 parts water; add ½ pint muriatic acid and ¾ pint sulphate of zinc; heat to 176° F. for 12 hours; then allow it to settle.

Cements to resist Sulphuric and Nitric Acids.—Silicate of potash (30° Baumé) and powdered pumice; or powdered asbestos 2, sulphate of baryta 1, silicate of soda 2 (50° Baumé, or 130° for dilute acids). For hot nitric acid, silicate of soda 2, sand 1, asbestos 1.

Marine Glue.—Pure india-rubber, 1 pint, dissolved by heat in mineral naphtha; when melted add, shellac, 2 pints, and cool on a slab.

Marine Glue, another.—Glue, 12 pints; water to dissolve, and yellow resin, 3 pints; melt, add turpentine, 4 pints, and mix.

Portable Glue for Draughtsmen.—Glue, 5 oz.; sugar, 2 oz.; water, 8 oz.; melt in water bath; cast in moulds; and dissolve for use in warm water.

Portable Glue for Thin Paper.—Gelatine, 1 lb., dissolved in water, and water evaporated till nearly expelled; add ½ lb. brown sugar, and pour into moulds.

Glue for Damp Wood.—Soak glue in water until soft; then dissolve in smallest amount of proof spirit by gentle heat; in 2 lbs. of the mixture dissolve 10 grains gum ammoniacum, and while liquid add half a drachm of mastic dissolved in 3 drachms rectified spirit.

Glue to resist Damp.—Boil linseed oil with ordinary glue.

Gum for Paper Labels.—Dextrine, 2 oz.; acetic acid, 1 oz.; water, 5 oz.; alcohol, 1 oz.; add the alcohol to the other ingredients when the dextrine is dissolved.

Cement for Papier Mache, Cards, &c.—Dissolve isinglass in alcohol and add sufficient rice flour to thicken; warm gently, and add a small quantity acetic acid.

Tough Cement for Paper, Cards, Linen, &c.—Mix 8 oz. rice flour with cold water; simmer gently, and then add 2 oz. glue dissolved in water, and alum 1 oz.

Tough Glue Cement.—Soak Russian glue for 12 hours in cold water; pour off the water, and add sufficient glacial acetic acid; dissolve in a hot water bath.

Glue to resist Moisture.—1 lb. glue melted in 2 quarts skimmed milk.

Glue to resist Moisture, another.—1 glue; 1 black resin; ¼ red ochre; melt and mix.

Thick Glue Cement to resist Moisture.—Shellac, 4 oz.; borax, 1 oz.; boil in a little water, and concentrate by heat to a paste.

Tough Glue Cement.—To ordinary glue add ¼ part vinegar and a little glycerine; mix plaster of paris with it to the required consistency.

Cement for Parchment and Card Board.—Powdered Chalk and a little glycerine mixed with common glue.

Litharge Cement.—Litharge, 1 oz; plaster of paris, 1 oz.; powdered resin, ⅛ oz.

Cementing Metal to Glass.—Copal varnish, 15: drying oil, 5; turpentine, 3; melt in a water bath, and add 10 parts slacked lime.

Cementing Metal to Glass; another.—Mix 2 parts powdered litharge and 1 part white lead; mix 3 parts boiled linseed oil with 1 part copal varnish, and stir the powder into the liquid.

Cement for Joining Metals to Wood.—Dissolve in boiling water, glue, 2¼ lb.; gum ammoniacum, 2 oz.; adding, in small quantities, 2 oz. sulphuric acid.

Cemont for Joining Metals to Earthenware.—Washed fine sand, 20 parts; litharge, 2 parts; powdered quicklime, 1 part; mix with boiled linseed oil, and colour with any pigment.

Cement for Iron Stove Pipes and for filling Cracks in Stoves.—Equal parts pulverised clay and fine wood ashes, and a little salt; mix with water to the consistency of putty.

Cement for Stoves and Ranges.—Mix fire clay, with a solution of silicate of soda.

Cement for Chemical Apparatus.—Melt and mix starch, glycerine, and gypsum to required consistency.

Cement for Joining Metals to Bone, Ivory, and Wood.—Mix litharge with glycerine to the required consistency.

Cement for Leather, Canvas, Cloth, Parchment, &c.—Melt and mix glycerine with glue.

Cement for Thick Leather.—Melt and mix glycerine with glue, and add pure tannin to proper consistency.

Pale Tough Cement.—Dissolve 75 parts of white indiarubber in 6 parts chloroform, and add 15 parts mastic and a little glycerine.

Porcelain Cement.—Add plaster of paris to a strong solution of alum.

Cement for Fastening Metal Tops on Oil Lamps.—5 parts water, boiled with 3 parts resin, 1 part of caustic soda, and mix with half its weight of plaster of paris.

Cement for Fixing Brass Letters on Glass.—Copal varnish, 15 parts; drying oil, 5 parts; turpentine, 2 parts; liquified marine glue, 5 parts; melt in a water bath, and add 10 parts dry slacked lime.

Tough Cement for Various Purposes.—Guttapercha, 1 lb.; indiarubber, 4 oz.; dissolved in bisulphide of carbon; pitch, 2 oz.; shellac, 2 oz.; boiled oil, 2 oz.; melted together.

White Cement for Shells and Various Purposes.—Best gelatine, 1 oz., dissolved in water; then add ½ drachm glacial acetic acid and a small quantity of powdered and sifted calcined oyster shells.

Cement for Coating Acid Troughs.—Melt together, 1 part pitch, 1 part resin, and 1 part plaster of paris.

Thick White Cement.—Resin, 4 oz.; beeswax, 1 oz.; plaster of paris, 5 oz.; borax, ½ oz.

Cement for Fixing Iron Bars into Stone.—A compound of equal parts of sulphur and pitch.

Indiarubber Cement.—Dissolve 2 oz. of pure white raw indiarubber in ½ pint benzoline or bisulphide of carbon; heat in a hot water bath.

Cutlers' Cement for fastening the Blades of Knives into Handles.—Resin, 4 parts; beeswax, 1 part; brickdust, 1 part. Another cement for the same is: resin, 4 parts; pitch, 4 parts; tallow, 2 parts; brickdust, 2 parts.

Cement for Box Wood and other Hard Woods.—Dissolve ¼ oz. isinglass in alcohol; and mix sugar, ½ oz.; box wood filings, 1 oz.; and add a little acetic acid.

Cement for Cementing Emery to Wood.—Melt and mix equal parts of shellac, white resin, and carbolic acid in crystals; add the acid after the others are melted.

Strong Paste Cement.—Glue, 1 part; flour, 4 parts; add sufficient water and boil gently; then add a little glacial acetic acid and mix well.

Paste for Labelling Tin and Iron, &c.—To ordinary paste add a small quantity each of glue and chloride of calcium. Another is: to 8 oz. of paste add 20 drops of a solution of chloride of antimony. And another is: 10 oz. mucilage of gum tragacanth; 10 oz. honey of roses; and 1 oz. flour.

Waterproof Cement.—Gelatine, 5 parts; solution of acid chromate of lime, 1 part; after using, expose the article to sunlight.

Waterproof Paste Cement.—To hot starch paste, add ½ its weight of turpentine and a small piece of alum.

Cement for Repairing Bronze and Zinc.—Mix powdered chalk and zinc-dust, and stir them into soluble glass solution of 30 B, until the mixture is fine and plastic.

Cement Lining for Inside of Cisterns.—Powdered brick, 2; quicklime, 2; wood ashes, 2; made into paste with boiled oil.

Cement for Seams and Joints of Stone Cisterns, &c.—Powdered brick, 6; white lead, 1; litharge, 1; mixed to a paste with boiled linseed oil.

Cement for Joining Porcelain Heads to Metal Bars.—Mix Portland cement with hot glue.

Cement for Fixing Tiles in Grates and Fireplaces.—Mix with hot glue, to the consistency of mortar, equal parts, sand, plaster of paris, and hair mortar.

Cement for Alabaster.—Melted alum.

Strong White Cement.—Mix finely powdered rice into a paste with cold water, add warm water to the proper consistency, boil for five minutes, and add a small quantity each of dissolved isinglass and acetic acid.

White Cement.—Plaster of paris mixed with alum water.

White Cement.—White lead, whiting, a small piece glycerine, well mixed with a little dissolved isinglass to the required consistency.

Common Black Sealing Wax.—Common resin, 6 lb.; yellow beeswax, ½ lb.; lamp black, 1 lb.

Common Red Sealing Wax.—Window glass resin, 6 lb.; white beeswax, ½ lb.; colour with venetian red.

Sealing Wax.—Venice turpentine, 4½ oz.; shellac, 9 oz.; colophony, 3 oz.; and enough pigment mixed with turpentine to colour it.

Sealing Wax.—Resin, 6 lb.; red ochre, 1 lb.; plaster of paris, ½ lb.; linseed oil, 1 oz.

Sealing Wax.—Resin, 50 parts; red lead, 37 parts; turpentine, 13 parts.

Shoemakers' Wax.—Melt equal parts pitch and resin; then add a little tallow; pour into water, and pull it into cords till tough; cut into pieces and keep in water.

Heel-ball.—Mix together beeswax and vegetable black, and enough resin to give it the required hardness.

Strong Cement.—Equal parts guttapercha and shellac, melted and mixed with a little white lead.

Tough Cement.—White raw indiarubber, 2 oz.; isinglass, ¼ oz.; guttapercha, 3 oz.; bisulphide of carbon, 8 oz.; heat in a hot water bath.

Cement for Fixing Paper on Glass.—Soak glue in vinegar, boil, and add flour to required consistency.

Cement for Worm-eaten Wood.—Mix whiting with phenic acid and essence of turpentine, and a little linseed oil; before applying, paint the wood over, and allow it to soak in, with a mixture of 1 oz. chili capsicum and 1 quart benzoline, properly dissolved

Cement for Filling up Cracks in Stove Grates.—Make a paste of pulverised iron and water glass.

Waterproof Cement used by Calico Printers.—1 lb. binacetate of copper and 3 lb. sulphate of copper, dissolved in 1 gallon of water, and the solution thickened with 2 lb. gum sanegal; 1 lb. British gum; 4 lb. pipe-clay, and 2 oz. nitrate of copper are afterwards added.

Cement for Fastening Cloth on to Metal and Wood Rollers.—Common glue and isinglass, equal parts; soak in small quantity of water for 10 hours; then boil, and add pure tannin till it becomes thick; apply hot.

Cement for Marble.—20 parts, fine sand; litharge, 2; dry slacked lime, 1; plaster of paris, 1; make into a putty with boiled linseed oil.

Cement to resist White Heat.—Pulverised clay, 4 parts; plumbago, 1; iron filings, free from oxide, 2; peroxide of manganese, 1; borax, ½; sea-salt, ½; mix with water to thick paste; use immediately, and heat gradually to a nearly white heat.

Jewellers' Cement.—Isinglass, ½ oz.; gum mastic, ½ oz.; gum ammoniacum, 1 drachm; dissolve in alcohol; heat and well mix.

Cabinet Makers' Cement for Fastening Cloth and Leather, &c., on to Wood.—Boil 1 lb. rye flour into a thick paste with water; next melt 3 oz. glue in a little water, and add 2 oz. treacle; add this mixture to the paste, and boil with water to the required consistency.

Non-conducting Cement, for Covering Boilers and Steam Pipes.—Portland cement, 1 part; flour, 2; fine sand, 1; sawdust, 4 parts; mix these dry, and then add, clay, 4 parts; plasterers' hair, ½ part; mix well together with water to the consistency of mortar; apply with a trowel to the thickness of an inch; when dry, apply successive coats of same thickness until from 5 to 7 inches thickness of composition is applied; let each coat dry before applying another, and finally give it 2 or 3 coats of tar.

Cement for Joints, to resist Great Heat.—Asbestos powder made into a thick paste, with liquid silicate of soda.

Cement for Steam and Water Joints.—Ground litharge, 10 lbs.; plaster of paris, 4 lbs.; yellow ochre, ½ lb.; red lead, 2 lbs.; hemp cut into ½ inch lengths, ½ oz.; mix with boiled linseed oil to consistency of putty.

Cement for Steam and Water Joints.—White lead, 10 parts; black oxide of manganese, 3; litharge, 1 part; mix with boiled linseed oil to consistency of putty.

Cement for Cisterns and Watercourses.—Powdered burnt clay, 50 parts; powdered fire brick, 40 parts; litharge, 10 parts; mix with boiled linseed oil to consistency of thin plaster. Wet the parts to be covered with water before applying.

Cement for Cisterns.—Ground litharge, 5 parts; concentrated glycerine, ½ part; plaster of paris, 4 parts; fine sand, 1 part; resin, ½ part; mix with boiled linseed oil to consistency of plaster.

Rust Joint Cement for Cast Iron Cisterns.—Cast iron borings, 5 lb.; powdered salammoniac, 1 oz.; flour of sulphur, 2 oz.; mix with water. If not required for immediate use, a better cement is composed of: cast iron borings, 6 lbs.; powdered salammoniac, 1 oz.; flour of sulphur, ½ oz.; mix with water.

NOTE.—The cubic contents in inches of the joint, divided by 5, will be approximately the weight of dry borings required to make the joint.

Red Lead Cement for Faced Steam Joints.—White lead, 1 part; red lead, 1 part; mix with boiled linseed oil to the consistency of putty.

Cement for Faced Steam Joints to stand Great Heat.—Plumbago, 1 part; red lead, 1; white lead, 1 part; mix with boiled linseed oil to consistency of putty.

Steam Joints.—Lead wire makes an excellent joint.

Cement for Furnaces.—Fire clay, 1 part; burnt fire clay, 1 part; mixed with sufficient silica of soda to make it plastic.

Cement for Leather Belts.—Guttapercha, 3; pure white raw indiarubber, 1; dissolved in 8 of bisulphide of carbon.

Cement for Leather Belts.—Another one is:—Guttapercha, 16; pure white raw indiarubber, 4; dissolve; then add pitch, 2; shellac, 1; boiled linseed oil, 2.

Turners' Cement.—Burgundy pitch, 2 lbs.; resin, 2 lbs.; yellow wax, 2 oz.; melt, and add 2 lbs. of whiting; pour out on a slab and roll into sticks.

Enamel Glaze Cement for Coating Iron Pans.—Flint glass, 130 parts; carb. soda, 20·5; boracic acid, 12 parts; dry at a temperature of 100 C.; heat to redness and anneal.

Cement for Fastening Leather on Iron Pulleys.—Soak for 10 hours 1 part crushed nut-galls in 8 parts water; strain, and apply hot to the leather. Pulley to be warmed and coated with glue mixed with a little treacle.

Another cement for same is:—1 part isinglass, 5 parts fish glue, dissolved in 6 parts water; then add gently 1 part nitric acid.

PAINTS, WOOD STAINS, AND VARNISHES.

Painting Machinery.—Rough castings spoil the look, and lower the value, of machinery. A nice smooth surface can be cheaply, and efficiently got up, as follows. First chip off all rough projections on the casting, and rub it hard all over with a piece of sandstone; next give it a coat of thin good oil paint. When dry, fill up all rough and hollow places with putty made of white lead, lampblack or dry lead paint, and gold size, which will set hard. Next thin the said mixture down to the consistency of treacle with spirits, and give the casting a coat of it. When dry, rub the casting down to a smooth surface with pumice stone and water, and give it two finishing coats of paint.

Tar Paint for Iron Work.—Gas tar, 7 parts; naphtha, 1 part.

Paint for Iron Work exposed to Weather.—Red oxide of iron, ground in oil, mixed with equal parts boiled linseed oil and turpentine, with 1 oz. of patent dryers to the lb.

Paint to prevent Dry Rot.—Wood tar, 1 part; train oil, 1 part; oil of cassia, 1 part; apply three coats of it.

Paint for Stone.—Browning's solution for protecting the surface of stone consists of 85½ per cent. by weight of benzoline; 10 of gum dammar; 2 of sugar of lead; 2 of wax, and ½ per cent. of corrosive sublimate. Apply with a brush, after having cleaned the surface of the stone.

Paint for Wire.—Mix linseed oil with as much litharge as will make it the required thickness; add $\frac{1}{10}$th part of lampblack. Boil for 3 hours, and apply in thin coats.

Flexible Paint for Canvas.—Yellow soap, 2½ lbs.; boiling water, 1½ gallons; dissolve and grind the solution while hot with 125 parts oil paint.

Paint for Blackboards.—Finely powdered pumice stone, 4 oz.; powdered rottenstone, 3 oz.; red lead, 1 oz.; lampblack, 8 oz.; glycerine, 1 oz.; mix and make into a paste with shellac varnish, and then add 2 quarts shellac varnish; apply 2 coats; stir well.

Anti-oxidation Paint.—Red lead, 8 parts; zinc in powder, 10 parts; dryers, 2 parts; linseed oil, 80 parts. Make only as much as is required for the time, and apply quickly when fresh.

Table 178.—COMPOSITION OF OIL VARNISHES.

	No. 1 Varnish.	No. 2 Varnish.	No. 3 Varnish.	No. 4 Varnish.	No. 5 Varnish.
	oz.	oz.	oz.	oz.	oz.
Amber	2	2	4	...	...
Shellac	...	...	1	...	...
Pale copal	...	...	...	4	...
Pale resin	...	...	...	...	3
Drying linseed oil	5	5	4	8	...
Oil of turpentine	6	5	8	12	8

Varnishes No. 1 and 2 are dissolved by heat. No. 3 varnish:—first dissolve the shellac; then add the amber, and dissolve by heat. No. 4 varnish:—boil the copal and drying oil until stiff; thin with the oil of turpentine, and strain.—No. 5 varnish dissolve.

Table 179.—COMPOSITION OF SPIRIT VARNISHES.

	No. 6 Varnish.	No. 7 Varnish.	No. 8 Varnish.	No. 9 Varnish.	No. 10 Varnish.	No. 11 Varnish.	No. 12 Varnish.	No. 13 Varnish.
	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.
Sandarac . .	2	8	...	4	2	...	1	1
Best shellac . .	1	...	5	2	5	10	5	4
Mastic . . .	½	...	...	1	...	2	1	1
Benzoin . . .	...	...	...	1	...	...	1	1
Powdered glass .	1	...	...	4	5	...	...	...
Venice turpentine .	1	2	1	2	2	...	...	1
Elemi . . .	½	...	...	...	1½	...	...	...
Alcohol . . .	6	32	32	32	24	32	32	32

Varnishes can be "paled" by adding 2 drachms of oxalic acid per pint of varnish. They can be coloured red with dragons' blood; brown, with logwood or madder; yellow, with aloes or gamboge; each digested in spirits and strained.

Colourless Spirit Varnish.—Dissolve 5 oz. best shellac in a quart of rectified spirits of wine; boil for a few minutes with 10 oz. of good well-burnt animal charcoal; filter first through silk and then through blotting-paper.

Colourless Spirit Varnish.—Dissolve bleached shellac in alcohol; when clear, pour off and add spirits of wine until the required thickness is obtained. Bleached shellac should be kept in the dark, and used immediately after bleaching.

Black Varnish.—Melt 1 lb. amber and add ½ pint hot linseed oil, and then add 3 oz. each of black resin and asphaltum; when nearly cold, add 1 pint oil of turpentine.

Ebonising Wood.—Mix logwood, 2 lbs.; tannic acid, 1 lb.; sulphate of iron, 1 lb.; apply hot.

Ebonising Wood.—Water, 2 gallons; logwood chips, 2 lbs.; black copperas, 1 lb.; logwood extract, 1 lb.; indigo blue, 1 lb.; lampblack, ¼ lb.; boil, cool, and strain, and add ½ oz. nut-galls.

Brunswick Black.—Melt 4 lbs. asphaltum; add 1 quart boiled linseed oil, and 1 gallon oil of turpentine.

To Remove Old Paint.—Use a strong solution of caustic soda. Another way is to use a mixture of 1 lb. pearlash and 3 lbs. quicklime and water; let it soak into the paint for 12 hours.

Renovating Polish for Wood Work.—Olive oil, 1 lb.; rectified oil of amber, 1 lb.; spirits of turpentine, 1 lb.; oil of lavender, 1 oz.; alkanet root, ½ oz. Another renovating polish is—pale linseed oil, 2 pints; strong distilled vinegar, ½ pint; spirit of turpentine, ¼ pint; muriatic acid, 1 oz.

Stains for Wood.—*Red.*—Brazil wood, 11 parts; alum, 4 parts. Boil. *Blue.*—Logwood, 7 parts; blue vitriol, 1 part; water, 22 parts Boil. *Black.*—Logwood, 9 parts; sulphate of iron, 1 part; water, 25 parts. Boil. *Green.*—Verdigris, 1 part; vinegar, 3 parts. Dissolve. *Yellow.*—French berries, 7 parts; water, 10 parts; alum, 1 part. Boil. *Purple.*—Logwood, 11 parts; alum, 3 parts; water, 29 parts. Boil.

Walnut Stain.—Boil 2 quarts of water, add 3 oz. washing soda, and then, by a little at a time, add 5 oz. vandyke brown; when the foaming ceases, add ½ oz. bichromate of potash.

Brown Stain.—Dissolve permanganate of potash in water.

Rosewood Stain.—Alcohol, 2 gallons; camwood, 3 lb.; red sanders, 1 lb.; aquafortis, ¼ lb. Apply 3 coats: rub with sandpaper; grain with iron rust; shade with asphaltum, thinned with turpentine. In staining wood, depth of colour may be obtained by giving several coats of stain; rub down with fine sandpaper, and give two coats of size before varnishing. For dark wood—varnish with French polish, 1 part; brown hard varnish, 2 parts. For light wood—varnish with 2 parts white French polish, and 3 parts white hard varnish.

Staining Floors.—*Oak Stain.* American potash, 2 oz.; pearlash, 2 oz.; water, 1 quart. *Mahogany Stain.*—Madder, 8 oz.; logwood chips, 2 oz.; boil in 1 gallon water, and apply hot. When dry, paint it over with a solution of—water, 1 quart; pearlash, 2 drachms; next, size and polish.

Polishing Stained Floors.—After sizing, apply the following polish, viz.: white wax, 4 parts; yellow wax, 8 parts; castile soap, 1 part; soft water, 20 parts; turpentine, 20 parts; the soap to be melted in the water, the wax to be dissolved in the turpentine. Mix the whole, brush it on the floor, and well rub with a cloth pad.

To Darken Mahogany.—Apply a solution of bichromate of potash.

Green Varnish for Metals.—Bronze green—strong vinegar, 2 quarts; mineral green, 1 oz.; raw umber, 1 oz.; salammoniac, 1 oz.; gum arabic, 4 oz.; French berries, 1 oz.; copperas, 1 oz.; dissolve with gentle heat, cool, and filter.

Green Transparent Varnish.—Chinese blue, 1 oz.; powdered chromate of potassa, 2 oz.; well ground and mixed; add a sufficient quantity of copal varnish and thin with turpentine.

Waterproof Varnish.—Dissolve guttapercha, 4 oz., resin, 2 oz., in bisulphide of carbon, and add 2 lb. hot linseed oil varnish.

Pattern Makers' Varnish.—Methylated spirit, 1 gallon; shellac, ½ lb.; plumbago, ½ lb.; dissolve and frequently stir.

Varnish for Drawings.—Dissolve by gentle heat, 8 oz. sandarac in 32 oz. alcohol. Another is—Dissolve 2 lb. mastic and 2 lb. dammar in 1 gallon turpentine, without heat. The drawing to be first sized, with a strong solution of isinglass and hot water.

COLOURING DRAWINGS.

MATERIAL.	COLOURS.
Brick to be erected in plans and sections	Crimson lake.
Brickwork in elevation	Crimson lake mixed with Venetian red.
Plaster	Light tint of burnt umber.
Granite	Pale Indian ink.
Stone generally	Yellow ochre or pale sepia.
Concrete work	Sepia with dark markings.
Clay or earth	Burnt umber.
Meadows	Hooker's green.
Slate	Indigo and lake.
Light coloured wood, such as pine	Raw sienna.
Graining	Burnt sienna.
Oak or teak	Vandyke brown.
Wrought iron	Prussian blue.
Cast iron	Payn's grey.
Steel	Indigo tinged with lake.
Lead	Pale Indian ink tinged with indigo.
Copper	Crimson lake.
Brass	Pale yellow.
Bronze	Darker yellow than brass.
White metal	White tinged with indigo.
Guttapercha	Dark sepia.
Vulcanised Indiarubber	Sepia tinged with indigo.
Leather	Light sepia.

SIZES OF DRAWING PAPER.

Demy	20 × 15 inches.
Medium	22 × 17 ,,
Royal	24 × 19 ,,
Super Royal	27 × 19 ,,
Imperial	30 × 21 ,,
Elephant	28 × 22 ,,
Columbier	34 × 23 ,,
Atlas	33 × 26 ,,
Theorem	34 × 28 ,,
Double Elephant	40 × 26 ,,
Antiquarian	52 × 31 ,,
Emperor	72 × 48 ,,

Gravity.—To find the velocity in feet per second acquired by a falling body.—*Rule:* Multiply the time in seconds by 32·2.

To find the height of the fall in feet.—*Rule:* Multiply the square of the time in seconds by 16·1.

To find the time in falling in seconds.—*Rule:* Divide the velocity in feet per second by 32·2.

To find the velocity in feet per second for a given height.—*Rule:* Multiply the height of the fall in feet by 64·4, and take the square root of the product.

Work accumulated in a Moving Body.—To find the force acquired by a weight in falling freely from a given height. -*Rule:* Multiply the weight in lbs. by the square of the velocity in feet per second, and divide by 64·4. The result is the accumulated work in foot pounds. Or another rule for the same is: Multiply the weight in lbs. by the height in feet of free fall. The product is the accumulated work in foot pounds, or the force that would raise a similar weight to a similar height.

The following examples of accumulated work show the application of these rules:—

To find the distance in feet a ball will traverse before coming to a state of rest, say, on a bowling green, at a velocity of 50 feet per second; weight of ball, 20 lbs., and the frictional resistance to its motion being $\frac{1}{10}$th the weight of the ball; then $\frac{50^2 \text{ velocity} \times 20 \text{ lbs. weight}}{2 \text{ lbs. frictional resistance} \times 64·4} = 338$ feet.

To find the distance in feet a train will move on a level rail, whose frictional resistance is 8 lbs. per ton, and supposing that there is no other resistance; the weight of the train being, say, 100 tons, and its velocity when the steam is shut off, 50 feet per second; then $\frac{50^2 \text{ velocity} \times 100 \text{ tons weight of train} \times 2{,}240 \text{ lbs.}}{100 \text{ tons weight} \times 8 \text{ lbs. per ton frictional resistance} \times 64·4} =$ 10869·5 feet before coming to rest.

Punching and Shearing Iron, &c., Plates.—*Punching.*—The resistance of a wrought-iron plate to punching is about the same as its resistance to tearing. Taking the maximum resistance at 25 tons per square inch, and the resistance to the punch being the area of the metal separated, or the circumference of the hole multiplied by the thickness of the plate, the force in tons required to punch a plate of wrought-iron is = circumference of the hole × its depth × 25. And a simple rule to find the force required to punch a plate is:—Multiply the diameter of the hole in 16ths of an inch by the thickness of plate in 16ths, and divide the product by 10; which result multiply by 3·1 for wrought iron plates; by 4·5 for steel plates; and by 2·5 for copper plates. The final product will be the required force in tons.

The compressive strength of a hardened steel punch is 100 tons per square inch. or four times greater than the maximum tensile strength of wrought-iron plates. The smallest size of hole that can be punched, is that of which the diameter is equal to the thickness of the plate.

Shearing.—The resistance of a wrought-iron plate to shearing is 20 per cent. less than its ultimate tensile strength; and the power required in tons to shear wrought-iron plates and bars may be found by the following rule: Multiply the square of the thickness of plate in 16ths of an inch by 8, and divide by 100.

Contraction of Metal in Casting.—Allowance per foot in length of pattern:—

	Inch.
Small cylinders (cast iron), castings	$\frac{1}{16}$
Large „ „ „	$\frac{3}{32}$
Toothed wheels „ „	$\frac{1}{10}$
General castings „	$\frac{1}{8}$
Bismuth castings	$\frac{5}{32}$
Gun metal, brass, and copper castings each	$\frac{3}{16}$
Tin and zinc castings each	$\frac{1}{4}$
Lead castings	$\frac{5}{16}$
Malleable iron castings	$\frac{1}{16}$ to $\frac{1}{4}$
Cast-steel castings	$\frac{3}{16}$ to $\frac{5}{16}$
Aluminium castings	$\frac{7}{32}$ to $\frac{9}{16}$

Depreciation of Machinery.—Amount to be deducted annually, commencing from the prime cost:—

	Per cent.
Lathes and machine tools, first class	10
Engines, shafting, gearing, and millwork	12½
Lathes and machine tools, second class	15
Machinery in general	10
Boilers	15
Leather belting	40

Depreciation of Factories.—Amount to be deducted annually, commencing from the original cost, of well built and well cared-for factories and workshops:—

	Per cent.
Factories, stone or brick built, without machinery	2
„ „ „ with machinery, ordinary	3
„ „ „ „ „ subjected to unusual amount of vibration	5
Factories, wooden buildings, or light iron buildings, without machinery	5
Factories, wooden buildings, or light iron buildings, with machinery	7
Foundries, stone or brick built	7½
Forges	10

When renewals are made to the carcase of the building, due to ordinary wear and tear, their cost should be added to the capital value at the date of the said renewal, and the same rate of depreciation should be continued.

Table 180.—WEIGHT, BULK, COMPOSITION, HEAT, AND EVAPORATIVE POWER OF COAL, AND OTHER FUELS.

Description of Coal.	Specific Gravity.	Weight and Bulk.		Composition per Cent.						Heat in Degrees F. to which 1 lb. of Water will be raised by 1 lb of the Fuel in conjunction with Oxygen.	Lbs. of Water heated from the Freezing Point to 212° F. by 1 lb. of Fuel.	Lbs. of Water at 212° F. converted into Steam by 1 lb. of Fuel.	Percentage of Coke produced from the Coals.
		1 Cubic Foot Solid.	Bulk of 1 Ton Heaped.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Sulphur.	Ash.				
		lbs.	Cubic ft.										
Welsh . .	1·31	82·	43	84	4·6	4·0	1·	1·5	4·9	14833	82·4	15·0	74
Newcastle . .	1·25	78·1	46	83	5·3	5·31	1·35	1·24	3·8	14796	82·2	14·9	61
Scotch . .	1·26	78·6	42	79	5·6	9·3	1·0	1·1	4·0	14150	78·6	14·3	54
Derbyshire .	1·29	80·6	48	80	4·9	10·0	1·4	1·0	2·7	13919	77·3	14·1	59
Lancashire .	1·27	79·4	46	78	5·3	9·1	1·3	1·4	4·9	13890	77·2	14·0	58
Yorkshire . .	1·29	80·6	48	80	4·9	10·0	1·4	1·0	2·7	13919	77·3	14·1	59
Coke .	0·75	48·	80	94	...	...	...	1·0	5·0	13800	77·2	14·0	
Peat dry . .	0·55	35·	200	60	6·	29·	1·	...	4·0	9940	55·1	10·0	
Wood, dry .	0·54	34·	140	50	6·	41·	1·	...	2·0	7870	44·3	8·0	
Straw . .	0·12	8·	280	36	5·	38·	·4	...	5·0	3935	22·1	4·0	

NOTE.—The average weight of loose coal heaped is 50 lbs. per cubic foot, and 45 cubic feet bulk per ton; and the average weight of loose coke heaped is 30 lbs. per cubic foot, and 80 cubic feet bulk per ton.

Pressure, Power and Discharge of Gas.—The total heat of coal gas is 690 units per cubic foot, its evaporative power is 1 lb. of water from 62° per cubic foot of gas. The pressure of gas is measured in inches of water; the pressure at the gas works is from 2 to 2½ inches of water, or a pressure of under 2 oz. per square inch. Gas weighs about 240 grains per cubic foot, or less than half the weight of air, which weighs about 560 grains per cubic foot. Gas has an ascending power equal to one inch of water for every 100 feet in height; it increases $\frac{1}{10}$ inch in pressure for every rise of 10 feet in height and decreases at the same rate in pressure for a descent. Each gas-burner consumes 5 cubic feet per hour, and the quantity of gas that can be supplied by various sizes of pipes at various distances from the supply pipe is given in the following table, which is useful for fixing gas stoves, &c.

Table 181.—NUMBER OF CUBIC FEET OF GAS DISCHARGED PER HOUR BY PIPES OF VARIOUS SIZES AND LENGTHS AT A PRESSURE OF $\frac{4}{10}$.

Length from the Supply Pipe	INTERNAL DIAMETER.										
	$\frac{5}{16}$ In.	$\frac{3}{8}$ In.	$\frac{7}{16}$ In.	½ In.	$\frac{5}{8}$ In.	¾ In.	1 In.	1¼ In.	1½ In.	1¾ In.	2 In.
10 feet.	40	63	93	130	228	360	738	1291	2037	2995	4185
20 ,,	28	45	66	92	161	254	522	913	1440	2118	2952
30 ,,	23	37	54	75	131	208	426	745	1176	1729	2415
40 ,,	20	32	46	68	114	180	369	645	1018	1497	2090
50 ,,	18	28	41	58	102	160	330	577	911	1339	1871
60 ,,	16	26	38	53	93	147	302	527	832	1223	1707
70 ,,	15	24	35	49	86	136	279	488	768	1132	1583
80 ,,	14	22	33	46	80	127	261	456	720	1059	1478
90 ,,	13	21	31	43	76	120	246	430	679	998	1396
100 ,,	12	20	29	41	72	114	233	408	644	947	1322
125 ,,	11	18	26	37	64	101	209	365	576	847	1184
150 ,,	10	16	24	33	58	93	190	334	528	773	1080
175 ,,	9	15	22	31	54	86	176	308	487	716	1000
200 ,,	9	14	20	29	51	80	165	288	455	669	935
225 ,,	...	13	19	27	48	76	156	274	430	630	880
250 ,,	...	12	18	26	46	72	147	258	407	599	836
300 ,,	...	...	17	24	41	65	137	236	376	547	764

Lifting Power of Gas.—About 30 cubic feet of coal gas, or about 13½ cubic feet of hydrogen gas, will lift 1 lb. weight.

Cupola.—One lb. of carbon burning to carbonic acid develops 12,906 units of heat, and the quantity of coke required to melt cast iron may be found thus:—2190, melting point,—50, temperature of the iron, × ·13 specific heat, = 278·2 units of heat to raise 1 lb. of metal to the melting point, and 278·2 + 233, latent heat of liquefaction of cast iron, = 511·2, total amount of heat required to melt 1 lb. Therefore, one ton of cast iron will require $\frac{2240 \times 511{\cdot}2\text{, total heat per lb.}}{12906 \times {\cdot}82 \text{ per cent. of carbon in the coke}} =$ 108·2 lbs. of coke, or nearly 1 cwt. of coke per ton of metal melted

WIND PRESSURE ON RAILWAY STRUCTURES.

The following is an extract from the report of a committee appointed to consider the question of wind pressure on railway structures.

In the case of high winds, with which alone we have to deal, it was found that the greatest pressure recorded in an hour was tolerably well proportional to the square of the mean velocity during the hour, and that the empirical formula $\frac{V^2}{100} = P$, where $V =$ maximum run in miles of the wind in any one hour and $P =$ maximum pressure in pounds on the square foot at any time during the storm to which V refers, represented very fairly the greatest pressure as deduced from the mean velocity for an hour. We have accordingly given a table calculated from the above formula for deducing maximum pressures from observed velocities.

Table 182.—Wind Velocities and Pressures.

Maximum hourly run of the wind in miles.	Maximum pressure in lbs on the sq. foot.	Maximum hourly run of the wind in miles.	Maximum pressure in lbs. on the sq. foot.	Maximum hourly run of the wind in miles.	Maximum pressure in lbs. on the sq. foot.
40	16·0	61	37·2	81	65·6
41	16·8	62	38·4	82	67·2
42	17·6	63	39·7	83	68·9
43	18·5	64	41·0	84	70·6
44	19·4	65	42·2	85	72·2
45	20·2	66	43·6	86	74·0
46	21·2	67	44·9	87	75·7
47	22·1	68	46·2	88	77·4
48	23·0	69	47·6	89	79·2
49	24·0	70	49·0	90	81·0
50	25·0	71	50·4	91	82·8
51	26·0	72	51·8	92	84·6
52	27·0	73	53·3	93	86·5
53	28·1	74	54·8	94	88·4
54	29·2	75	56·2	95	90·3
55	30·2	76	57·8	96	92·2
56	31·4	77	59·3	97	94·1
57	32·5	78	60·8	98	96·0
58	33·6	79	62·4	99	98·0
59	34·8	80	64·0	100	100·0
60	36·0				

From the consideration we have given to the subject, we are of opinion that the following rules will sufficiently meet the cases referred to us :—

(1) That for railway bridges and viaducts a maximum wind pressure of 56 lbs. per square foot should be assumed for the purpose of calculation.

(2) That where the bridge or viaduct is formed of close girders, and the tops of such girders are as high or higher than the top of a train passing over the bridge, the total wind pressure upon such bridge

or viaduct should be ascertained by applying the full pressure of 56 lbs. per square foot to the entire vertical surface of one main girder only. But if the top of a train passing over the bridge is higher than the tops of the main girders, the total wind pressure upon such bridge or viaduct should be ascertained by applying the full pressure of 56 lbs. per square foot to the entire vertical surface from the bottom of the main girders to the top of the train passing over the bridge.

(3) That where the bridge or viaduct is of the lattice form or of open construction, the wind pressure upon the outer or windward girder should be ascertained by applying the full pressure of 56 lbs. per square foot, as if the girder were a close girder, from the level of the rails to the top of a train passing over such bridge or viaduct, and by applying in addition the full pressure of 56 lbs. per square foot to the ascertained vertical area of surface of the ironwork of the same girder situated below the level of the rails or above the top of a train passing over such bridge or viaduct. The wind pressure upon the inner or leeward girder or girders should be ascertained by applying a pressure per square foot to the ascertained vertical area of surface of the ironwork of one girder only situated below the level of the rails or above the top of a train passing over the said bridge or viaduct, to this scale, viz. :—

(*a*) If the surface area of the open spaces does not exceed two-thirds of the whole area included within the outline of the girder, the pressure should be taken at 28lbs. per sq. foot.

(*b*) If the surface area of the open spaces lie between two-thirds and three-fourths of the whole area included within the outline of the girder, the pressure should be taken at 42lbs. per square foot.

(*c*) If the surface area of the open spaces be greater than three-fourths of the whole area included within the outline of the girder, the pressure should be taken at the full pressure of 56lbs. per square foot.

(4) That the pressure upon arches and the piers of bridges and viaducts should be ascertained as nearly as possible by the above rules.

(5) That in order to ensure a proper margin of safety for bridges and viaducts in respect of the strains caused by wind pressure, they should be made of sufficient strength to withstand a strain of four times the amount due to the pressure calculated by the foregoing rules. And that, for cases where the tendency of the wind to overturn structures is counteracted by gravity alone, a factor of safety of 2 will be sufficient.

The Pressure of Wind on Roofs of buildings seldom exceeds 40lbs. per square foot in this country, except in great storms, when it may be 50lbs. per square foot. In countries subject to hurricanes the wind pressure is sometimes from 60 to 70lbs. per square foot.

Table 146.—List of Minerals.

Arsenical Iron, an ore containing variable proportions of iron, arsenic, and sulphur, used in the manufacture of white arsenic.

Azurite, a valuable azure blue ore of copper, containing about 55 per cent. copper, with carbonic acid and water.

Bismuth Ochre, an oxide of bismuth found in Saxony, Bohemia, and Siberia.

Bornite, the principal Chilian ore of copper, containing about 59 per cent. copper, with iron and sulphur.

Cassiterite, or Tinstone, the commonest ore of tin, containing about 93 per cent. pure tin.

Ceruscite, an ore of lead, containing about 83 per cent. metal.

Chalcoite, an ore of copper, 75 per cent. metal, with sulphur.

Chalcopyrite, copper 33, iron 33, sulphur 33 per cent., the principal ore in Cornwall.

Chromic Iron } the ore of chromium, containing chromium from 27 to 40
Chromite } per cent., with iron and other metals.

Cinnabar, sulphide of mercury; the common ore yields about 80 per cent. metal.

Cobaltite, cobalt 33 per cent., with iron, arsenic, and sulphur.

Copper Pyrites, *see* Chalcopyrite,

Cuprite, a Chilian ore of copper, containing about 88 per cent. of metal.

Franklinite, an uncommon ore of iron and zinc, containing iron 45, manganese 9, zinc 20, oxygen 26.

Galenite, the only important ore of lead, containing about 75 per cent. of metal, with sulphur and sometimes silver, gold, and other metals.

Hematite, one of the commonest iron ores, containing about 75 per cent. metal, and called by different names.

Ilmenite, titaniferous iron ore, sometimes containing gold.

Iron Glance, specular iron ore, q. v.

Iron Minium, red ochre, q. v.

Kidney Ore, a hard bubble-shaped form of hematite iron ore.

Limonite, the iron mineral which is the basis of bog ores, ochres, &c., containing about 60 per cent. metal.

Magnetic Iron Ore } the most valuable and common ore of iron, con-
Magnetite } taining about 72 per cent. metal.

Malachite, a valuable copper ore, containing about 50 per cent. of metal, much used for ornaments.

Manganite, an ore of manganese, containing about 62 per cent.

Micaceous Iron Ore, a scaly variety of hematite.

Millerite, an ore of nickel, containing 64 per cent., with sulphur.

Minium, one of the scarcer ores of lead, containing 90 per cent. of metal, with oxygen.

Molybdenum, a white brittle metal, very infusible.

Niccolite, an important ore of nickel, containing 44 per cent. of metal, with arsenic.

Oligiste, a specular iron ore, q. v.

Orpiment, a lemon-yellow arsenic ore, containing 61 arsenic, with 39 sulphur; not much used as ore.

Puddlers' Ore, an unctuous form of hematite used in Cumberland for lining the hearths of puddling furnaces.

Pyrite, a variable ore of iron, containing iron about 42, with sulphur and other metals.

Pyrolusite, an ore of manganese, used in glass and bleaching powder making, containing about 60 per cent. manganese.

Realgar, a bright red sulphide of arsenic.

Red Hematite, the smelter's name for all iron ores consisting chiefly of anhydrous peroxide of iron.

Red Ochre, a compact earthy variety of hematite.

Rother Glaskopf, kidney ore (iron).

Siderite, an important ore of iron, consisting of ferrous carbonate.

Smaltite, an ore of cobalt, found in Saxony, used for making smalt.

Smithsonite, a carbonate of zinc, much used as an ore, containing about 50 per cent. metal.

Specular Iron Ore, brilliant crystallised hematite.

Sphalerite, an abundant ore of zinc, containing about 60 per cent., with sulphur and other metals.

Stibium } the principal ore of antimony, containing about 70 per cent. of
Stibnite } metal; the black antimony of the shops is this, fused.

Tetrahedrite, an ore of copper of variable composition, containing 19 to 25 per cent. of copper, with sulphur and other metals.

Tin Stone, cassiterite.

Titaniferous Iron Ore, ilmenite.

Wad, black manganese ore, of variable composition.

Zincite, an ore of zinc yielding about 80 per cent.

Table 147.—DESCRIPTION OF CHEMICAL AND MINERAL SUBSTANCES.

Acetate of Copper is verdigris.

Alum is sulphate of aluminia.

Aquafortis is nitric acid.

Bleaching Powder is chloride of lime and hydrochloric acid.

Blue Billy for lining furnaces, is pure oxide of iron

Blue Stone or Blue Vitriol is sulphate of copper.

Boiler Scale is carbonate of calcium.

Burnett's Disinfecting Fluid is chloride of zinc solution.

Calamine is carbonate of zinc.

Calcium is the metallic base of lime.

Calomel is chloride of mercury.

Carbon is pure charcoal.

Cast-Iron, Grey, is composed of iron 90·5 parts; combined carbon 1·5; graphite 2·8; silicon 3·1; sulphur 1·1; manganese ·6; and sulphur ·4 parts.

Chalk is carbonate of lime.

Chloroform is chloride of formyle.

Citric Acid is a lemon juice preparation.

Common Salt is chloride of sodium.

Copperas, or Green Vitriol, is sulphate of iron.

Corrosive Sublimate is bichloride of mercury.

Dentist's Succedaneum is an amalgam of silver filings and mercury.

Dextrine is a gum prepared from potato starch.

Dry Alum is sulphate of aluminia and potash.

Ebonite is India-rubber mixed with half its weight of sulphur.

Emerald Green is sesquioxide of chromium.

Epsom Salts is sulphate of magnesia.

Ethiops Mineral is black suphide of mercury.

Ferro-Manganese is pig iron containing more than 20 per cent. of manganese.

Flake White is oxidized carbonate of lead.

Fluor Spar is a mineral composed of fluoride of calcium.

Flux, Black, is a mixture of carbonate of potash and charcoal.

Galena is sulphide of lead.

Glass used for Windows is composed of silica 68·8 parts; lime 13; alumina 7; and soda 11·2 parts.

Glauber's Salts is suphate of soda.

Glucose is grape sugar and potato starch.

Glycerine is fat, decomposed with high pressure steam.

Goulard is oxide of lead.

Gunpowder consists of nitre 75; charcoal 15; and sulphur 10 parts.

Iron Pyrites is bisulphide of iron.

Jeweller's Putty is oxide of tin.

Kaolin is a composition of silica and alumina.

King's Yellow is sulphide of arsenic.

Lamp Black is the soot from the smoke of burning pitch.

Laughing Gas is protoxide of nitrogen.

Lime is the oxide of calcium.

Litharge is monoxide of lead.

Lithia is oxide of lithium.

Lunar Caustic is nitrate of silver.

Marl is an earth, containing carbonate of lime

Marmolite is silicate of magnesia.

Massicot is yellow oxide of lead.

Meerschaum is silicated magnesian clay.
Metallic Oxide is a metal combined with oxygen.
Mica is a transparent mineral.
Mosaic Gold is bisulphide of tin.
Muriate of Soda is common salt.
Nitre, or Saltpetre, is nitrate of potash.
Ochre is the hydrated sesquioxide of iron.
Oil of Vitriol is sulphuric acid.
Prussian Blue is prussiate of potash.
Putty Powder is levigated oxide of tin.
Red Lead is oxide of lead.
Rochelle Salt is tartrate of potash.
Rust of Iron is oxide of iron.
Salt of Lemons is oxalic acid.
Size is an impure gelatin, prepared from hides, &c.
Slag of Blast Furnaces is composed of silica 36 parts; lime 38; alumina 14; magnesia 7; ferrous oxide 1·5; manganese oxide 1·4; and calcium sulphide 2·1 parts.
Smelling Salt is carbonate of ammonia.
Soap Stone is a magnesian mineral.
Soda is oxide of sodium.
Soda Ash is carbonate of sodium.
Spiegeleisen is pig-iron rich in carbon and manganese.
Spirit of Salt is hydrochloric acid.
Spirits of Hartshorn is ammonia.
Stalactite is carbonate of lime.
Stucco, or Plaster of Paris is sulphate of lime.
Sugar of Lead is acetate of lead.
Talc is a magnesian mineral.
Vermilion is sulphide of mercury.
Vinegar is acetic acid.
Volatile Alkali is ammonia.
Volatile Salt is ammonia.
Vulcanite is India-rubber mixed with half its weight of sulphur
Washing Crystals is crystallised soda and 2 per cent borax.
Water is oxide of hydrogen.
White Lead is carbonate of lead.
White Manganese is carbonate of manganese.
White Precipitate is a compound of ammonia and corrosive sublimate
White Pyrites is a sulphuret of iron.
White Vitriol is sulphate of zinc.
Whiting is purified carbonate of lime.
Zinc Chloride is zinc dissolved in hydrochloric acid.
Zinc White is oxide of zinc.
Zinkenite is an ore of antimony and lead.

MEASURES RELATING TO BUILDING.

Rood of masonry = 36 square yards face, 2 feet thick.

Load of sand = 36 bushels.

Load of unhewn or rough timber = 40 cubic feet.

Load of hewn or squared timber, reckoned to weigh 20 cwt. = 50 cubic feet.

Load of 1 inch plank = 600 square feet.

Load of plank more than 1 inch thick = 600 divided by the thickness in inches. Thus—a load of 2 inch planks equals 300 square feet.

Planks, section 11 × 3 inches. Deals, section 9 × 3 inches. Battens, section 7 × 2½ inches. A reduced deal is 1½ inches thick × 11 inches wide × 12 feet long.

Load of lime = 32 bushels.

A load of mortar is equal to 1 cubic yard.

A hod of mortar measures 9 × 9 inches.

2 hods of mortar are nearly equal to a bushel.

The mortar in a rod of brick work (4,500 bricks) is taken at 1½ cwt. of chalk lime and 2 loads of sand, or 1 cwt. of stone lime and 2½ loads of sand.

Load of bricks = 500.

Size of bricks = 9 inches long × 4½ inches broad × 2¾ inches thick.

32 bricks laid flat, or 48 laid on edge will pave 1 square yard.

Number of bricks in a cubic yard = 384.

A rod of brick work measures 16½ feet × 16½ feet × 1⅛ foot = 306 cubic feet or 11⅓ cubic yards.

A rod of brick work = 272 superficial feet, 1½ brick thick.

To reduce brick work from superficial feet of 9 inches thick, to the standard thickness of 13½ inches, deduct ⅓rd.

To reduce brick work from cubic feet, to superficial feet of the standard thickness of 13½ inches, deduct ⅑th.

Rod of brickwork = 15 tons

1000 plain tiles = 21 cwt.

1000 pantiles = 47 cwt.

1000 9-inch paving tiles = 58 cwt.

1000 10-inch paving tiles = 72 cwt.

1000 12-inch paving tiles = 107 cwt.

1000 stock bricks = 45 cwt.

1000 paviors = 49 cwt.

Hundred of lime = 35 bushels.

Hundred of nails or tacks = 120 in number.

Thousand of nails or tacks = 1,200 in number

Hundred of lead = 112 lbs.

A fodder of lead = 19½ cwt.

Sheet lead = 6 to 10 lbs. per square foot

A table of glass = 5 feet. A case of glass = 45 tables. A case of Newcastle and Normandy glass = 25 tables. A stone of glass = 5 lbs. A seam of glass = 24 stone. A square of flooring = 100 square feet. A hundred of deals = 120 in number. A cord of wood = 4 feet × 4 feet × 8 feet = 128 cubic feet. A stack of wood = 108 cubic feet.

Bricks and Brickwork.—Good bricks should give a clear, ringing metallic sound when struck, and they should not absorb more than one-sixth of their weight of water. Bricks weigh as follows:—

London stock bricks,	size in inches	$8\frac{3}{4} \times 4\frac{1}{4} \times 2\frac{3}{4}$	weight each	$6\frac{3}{4}$ lbs.
Red kiln .	„ „	$8\frac{3}{4} \times 4\frac{1}{4} \times 2\frac{3}{4}$	„	7 „
Welsh fire .	„ „	$9 \times 4\frac{1}{2} \times 2\frac{3}{4}$	„	$7\frac{3}{4}$ „
Paving .	„ „	$9 \times 4\frac{1}{2} \times 1\frac{3}{4}$	„	5 „
Plain roofing tiles .	„	$10\frac{1}{2} \times 6\frac{1}{2} \times \frac{5}{8}$	„	$2\frac{1}{2}$ „
Pantiles . . .	„	$13\frac{1}{2} \times 9\frac{1}{2} \times \frac{1}{2}$	„	$5\frac{1}{4}$ „
Paving tiles . .	„	$6 \times 6 \times 1$	„	$2\frac{1}{4}$ „
Stone paving .	„	$12 \times 12 \times 2$	„	27 „

The weight of bricks is approximately 175 lbs. per cubic foot when set in mortar, and 125 lbs. per cubic foot when set in cement.

The expansion of common stock-bricks by heat in rising from 32° Fahr. to 212° Fahr. is generally ·00363, and of fire-brick it is ·00047.

The resistance of bricks to fracture is generally approximately one-half of the crushing load. The tensile strength of good bricks is approximately 275 per square inch.

The number of bricks required for 100 superficial feet of area of the face of a wall is = 551 for each half brick the wall is thick.

The Working-loads on Foundations, and also on brick-work and stone-work, should not generally be greater than as follows:—

	Tons per square foot.
Soft soil	1·00
Moist clay and sand, protected against lateral spreading .	1·33
Loose impermeable beds, with piling	1·75
Rubble masonry	2·00
Lime-concrete: Coarse sand and dry clay	2·25
Loose impermeable beds, with piling and concrete . .	2·65
Brickwork in cement	2·75
Firmly bedded broken stones on dry clay	3·00
Piers of brickwork, ordinary good	2·00
Piers of hard brickwork, set in mortar	3·50
Piers of hard brickwork, set in cement	5·50
Sandstone piers	8·00
Bath stone piers	12·50
Granite piers	14·50
Portland stone piers	39·00

The height of piers of brick or stone should not exceed 12 times their least thickness at the base.

Table 183.—HEIGHT OF ROOFS AND WEIGHT OF ROOFING.

Kind of Covering.	Height of Roof in parts of Span.	Weight upon a square foot of Roofing.
		lbs.
Copper covering	$\frac{1}{48}$	1
Roofing felt	$\frac{1}{8}$	$1\frac{1}{4}$
Corrugated iron, average	$\frac{1}{5}$	$1\frac{1}{2}$
Zinc, average	$\frac{1}{48}$	$1\frac{3}{4}$
Boarding $\frac{3}{4}$ inch thick	$\frac{1}{4}$	3
Pantiles	$\frac{2}{9}$	$6\frac{1}{2}$
Thatch of straw or heather	$\frac{1}{2}$	7
Lead	$\frac{1}{48}$	8
Slates, ordinary	$\frac{1}{4}$	9
Plain tiles	$\frac{2}{7}$	18
Stone slate	$\frac{2}{7}$	24
Pressure of snow per inch in depth, may be		$0\frac{3}{4}$

Table 184.—MAXIMUM SAFE WORKING LOADS ON METALS AND WOODS.

Metals.	Working Tensile Stress in Tons per Square Inch.	Working Crushing Stress in Tons per Square Inch.	Woods.	Working Tensile Stress in Tons per Square Inch.	Working Crushing Stress in Tons per Square Inch.
Manganese steel	10	6·0	Greenheart	1·00	1·50
Nickel steel. 3 Ni.	9	5·3	Hornbeam	1·00	·60
Manganese bronze	$7\frac{1}{2}$	4·7	Lignum-vitæ	·65	·55
Cast-steel castings	7	4·5	Teak and Beech	·62	·52
Mild steel	7	4·0	Sabicu	·32	·50
Aluminium bronze 10 Al.	7	4·5	Oak, English	·60	·50
			Ash, English	·50	·45
Wrought-iron, best Yorkshire	6	3·0	Memel	·50	·40
			White Deal	·47	·38
Wrought-iron	5	3·0	Pitch Pine	·45	·36
Copper „	3·5	—	Mahogany and Walnut	·42	·35
Bronze	3·3	1·5	Red Pine and Jarrah	·40	·33
Gun-metal	3·0	1·2	Yellow Pine	·30	·25
Brass	2·5	1·0			
Cast-iron	1·5	5·0			

Table 185.—COMPOSITION OF MORTAR AND CEMENTS.

	Lime.	Sand.		Lime.	Sand.
Mortar	1	3	Cement: 1 Portland cement	—	3
Mortar: 1 ground ashes or coke	1	2	Mastic cement: linseed oil mixed with 1 red lead	5	5
Mortar for foundations: 1 lias lime	—	3			

Strength of Cements and Concrete.—The strength of cements and concrete increases gradually until they have been set one year, when their maximum strength is generally attained. They vary so considerably in quality that their strength cannot be averaged, but it is sometimes as given in the following tables:—

Table 186.—APPROXIMATE TENSILE STRENGTH, IN LBS. PER SQUARE INCH, OF CEMENTS AND CONCRETE.

Description.	Age 1 Month.	Age 2 Months.	Age 4 Months.	Age 6 Months.	Age 9 Months.	Age 12 Months.
Cements.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Pure Portland cement	500	550	600	700	750	800
1 cement, 1 sand	200	300	400	425	450	500
1 cement, 2 sand	175	250	275	300	325	350
1 cement, 3 sand	150	200	225	250	275	300
1 cement, 5 sand	100	125	150	160	180	200
Concrete.						
1 cement, 1 small gravel	250	350	400	450	500	600
1 cement, 2 coarse gravel	200	300	350	400	450	500
1 cement, 3 small gravel	100	150	200	250	300	400

Table 187.—APPROXIMATE CRUSHING STRENGTH, IN LBS. PER SQUARE INCH, OF CEMENTS AND CONCRETE.

Description.	Age 1 Month.	Age 2 Months.	Age 4 Months.	Age 6 Months.	Age 9 Months.	Age 12 Months.
Cements.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Pure Portland cement	5000	5500	6000	7000	7500	8000
1 cement, 1 sand	1400	2100	2800	2970	3150	3500
1 cement, 2 sand	1050	1500	1650	1800	1950	2100
1 cement, 3 sand	750	1000	1125	1250	1370	1500
1 cement, 5 sand	400	500	600	640	720	800
Concrete.						
1 cement, 1 small gravel	1500	2100	2400	2700	3000	3600
1 cement, 2 coarse gravel	1200	1800	2100	2400	2700	3000
1 cement, 3 small gravel	400	600	800	1000	1200	1600

Table 188.—APPROXIMATE CRUSHING STRENGTH OF VARIOUS KINDS OF BRICKS.

Description.	Fracture may begin with a Crushing Force per Square Foot of	Crushing Force per Square Foot.
	Tons.	Tons.
Red bricks	7	50
Yellow-faced bricks, baked	8	64
Yellow-faced bricks, burned	28	92

Table 188 *continued.*—APPROXIMATE CRUSHING STRENGTH OF VARIOUS KINDS OF BRICKS.

Description.	Fracture may begin with a Crushing Force per Square Foot of	Crushing Force per Square Foot.
	Tons.	Tons.
London stock-bricks, best	32	95
London stock-bricks, common	10	45
Hard stock-bricks, best	42	150
Gault bricks, common	10	34
Gault bricks, best pressed	45	160
Staffordshire blue bricks	—	445
Staffordshire blue bricks, Hamblet's	—	820
Vitrified granite bricks, Candy's	—	444
Stourbridge fire-clay bricks	—	102

TRANSMISSION OF POWER

BELTING.—*To find the horse-power which can be transmitted by single leather belts.*—Multiply the breadth of belt in inches by 70, and by the speed of belt in feet per minute; and divide by 33,000. The quotient is the horse-power.

Double belts transmit 1½ times as much power as single belts.

To find the width of single belt for transmitting a given horse-power.—Multiply the horse-power by 33,000, and divide by 70 times the speed of the belt in feet per minute. The quotient is the width of belt in inches.

These rules are sufficiently approximate where there is no great degree of inequality in the diameters of the pulleys.

SHAFTING.—*To find the horse-power which can be transmitted by a wrought iron shaft.*—Multiply the cube of the diameter of the shaft in inches by the number of revolutions per minute, and divide by 80. The quotient is the horse-power.

To find the diameter of a wrought iron shaft required to transmit a given horse-power.—Multiply the horse-power by 80, and divide by the number of revolutions per minute. The cube root of the quotient is the diameter in inches.

ROPES.—*To find the horse-power that can be transmitted by ropes.*—Multiply the sectional area of one rope in square inches by 100 times the speed of the rope in feet per minute, and divide by 33,000. The quotient is the horse-power for one rope.

Or, multiply the sectional area of one rope by the speed, and divide by 330.

TOOTHED WHEELS.—*To find the horse-power that can be transmitted by toothed wheels.*—Multiply the velocity of the pitch-line in feet per second by the breadth of the teeth in inches, and by the square of the pitch in inches, and divide by 15. The quotient is the horse-power.

For bevel wheels, the mean diameter and mean pitch are to be taken.

Driving Power of Leather Belts.

Diameter of Pulley.	Revolutions of the Pulley per Minute.											
	50	60	70	80	90	100	125	150	175	200	250	300
	Horse-Power Transmitted by each Inch Wide of Single Belt.											
Inches.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.
12	·20	·24	·28	·32	·35	·39	·49	·59	·69	·79	·98	1·18
14	·23	·28	·32	·37	·41	·46	·57	·69	·80	·92	1·14	1·38
16	·26	·32	·37	·42	·47	·53	·66	·79	·92	1·05	1·31	1·58
18	·30	·35	·41	·47	·53	·59	·74	·89	1·04	1·18	1·48	1·77
20	·33	·39	·46	·52	·59	·65	·82	·98	1·14	1·31	1·64	1·96
24	·39	·47	·55	·63	·71	·79	·98	1·18	1·38	1·58	1·97	2·36
28	·46	·55	·64	·73	·83	·92	1·15	1·38	1·61	1·84	2·29	2·75
32	·52	·63	·73	·84	·94	1·05	1·31	1·57	1·84	2·10	2·63	3·15
36	·59	·71	·83	·95	1·06	1·18	1·48	1·77	2·06	2·36	2·96	3·55
40	·65	·79	·92	1·04	1·18	1·31	1·64	1·96	2·29	2·62	3·27	3·94
44	·72	·87	1·01	1·15	1·30	1·45	1·80	2·16	2·53	2·89	3·60	4·34
48	·79	·94	1·10	1·26	1·42	1·57	1·96	2·36	2·75	3·15	3·93	4·72
54	·89	1·06	1·24	1·42	1·59	1·77	2·22	2·66	3·10	3·55	4·34	5·31
60	·98	1·18	1·38	1·57	1·77	1·96	2·46	2·95	3·44	3·93	4·91	5·90
66	1·08	1·30	1·52	1·73	1·95	2·17	2·71	3·25	3·79	4·33	5·41	6·50
72	1·18	1·42	1·65	1·89	2·13	2·36	2·95	3·54	4·13	4·72	5·90	7·10
78	1·28	1·53	1·79	2·04	2·30	2·56	3·20	3·84	4·48	5·11	6·40	7·68
84	1·38	1·65	1·93	2·21	2·48	2·75	3·44	4·13	4·81	5·51	6·89	8·28
90	1·48	1·77	2·06	2·36	2·66	2·96	3·68	4·43	5·18	5·90	7·38	8·85
96	1·57	1·89	2·21	2·53	2·84	3·15	3·95	4·73	5·51	6·31	7·89	9·45

Monel Metal—Physical Constants.

Density	8·80	Elect. resist'y (at 0° C.)—	
lbs. per cu. in. . .	0·318	micro—cm.³ . . .	42·5
Melting point . . .	1350° C.—2460° F.	ohm—mil—ft. . .	256
Specific heat (20°—400° C.) .	·127	Modulus in tension, psi . .	25–26 × 10⁶
Co-ef. expansion (25°—100° C.)	·000014	Modulus in torsion, psi . .	8–9 × 10⁶
(25°—300° C.) .	·000015	Magnetic transformation .	95° C.—203° F.
Heat cond'y (0°—100° C.) .	⅛th that of Commercial Copper		

HORSE-POWERS OF SINGLE AND DOUBLE LEATHER BELTS.

When estimating Belt Velocities on normal size pulleys, provide or 2½ per cent. creep.

SINGLE LEATHER BELTS 5 M.M SUBSTANCE

Velocity in Feet per Minute.	Width of Belt in Inches										
	2	3	4	5	6	7	8	9	10	11	12
500	1·78	2·67	3·56	4·45	5·34	6·23	7·12	8·01	8·90	9·79	10·68
750	2·67	4·005	5·34	6·675	8·01	9·345	10·68	12·015	13·35	14·685	16·02
1000	3·56	5·34	7·12	8·90	10·68	12·46	14·24	16·02	17·80	19·58	21·36
1250	4·45	6·675	8·90	11·125	13·35	15·575	17·80	20·025	22·25	24·475	26·70
1500	5·34	8·01	10·68	13·35	16·02	18·69	21·36	24·03	26·70	29·37	32·04
1750	6·23	9·345	12·46	15·575	18·69	21·805	24·92	28·035	31·15	34·265	37·38
2000	7·12	10·68	14·24	17·80	21·36	24·92	28·48	32·04	35·60	39·16	42·72
2250	7·91	11·865	15·82	19·775	23·73	27·685	31·64	35·595	39·55	43·505	47·46
2500	8·70	13·05	17·40	21·75	26·10	30·45	34·80	39·15	43·50	47·85	52·20
2750	9·50	14·25	19·00	23·75	28·50	33·25	38·00	42·75	47·50	52·25	57·00
3000	10·30	15·45	20·60	25·75	30·90	36·05	41·20	46·35	51·50	56·65	61·80
3250	10·95	16·425	21·90	27·375	32·85	38·325	43·80	49·275	54·75	60·225	65·70
3500	11·60	17·40	23·20	29·00	34·80	40·60	46·40	52·20	58·00	63·80	69·60
3750	12·20	18·30	24·40	30·50	36·60	42·70	48·80	54·90	61·00	67·10	73·20
4000	12·80	19·20	25·60	32·00	38·40	44·80	51·20	57·60	64·00	70·40	76·80
4250	13·35	20·025	26·70	33·375	40·05	46·725	53·40	60·075	66·75	73·425	80·10
4500	13·90	20·85	27·80	34·75	41·70	48·65	55·60	62·55	69·50	76·45	83·40
4750	14·30	21·45	28·60	35·75	42·90	50·05	57·20	64·35	71·50	78·65	85·80
5000	14·70	22·05	29·40	36·75	44·10	51·45	58·80	66·15	73·50	80·85	88 20

DOUBLE LEATHER BELTS 9 M.M SUBSTANCE.

Velocity in Feet per Minute	Width of Belt in Inches.									
	6	8	10	12	14	16	18	20	24	30
500	8·16	10·88	13·60	16·32	19·04	21·76	24·48	27·20	32·64	40·80
750	12·24	16·32	20·40	24·48	28·56	32·64	36 72	40·80	48·96	61·20
1000	16 32	21·76	27·20	32·64	38·08	43·52	48·96	54·40	65·28	81·60
1250	20·40	27·20	34·00	40·80	47·60	54·40	61·20	68·00	81·60	102·00
1500	24·48	32·64	40·80	48·96	57·12	65·28	73·44	81·60	97·92	122·40
1750	28·56	38 08	47·60	57·12	66·64	75·16	85·68	95·20	114·24	142·80
2000	32·64	43·52	54·40	65·28	76·16	87·04	97·92	108·80	130·56	163·20
2250	36·12	48·16	60·20	72·24	84·28	96·32	108·36	120·40	144·48	180·60
2500	39·60	52·80	66·00	79·20	92·40	105·60	118·80	132·00	158·40	189·00
2750	43·50	58·00	72·50	87·00	101·50	116·00	130·50	145·00	174·00	217·50
3000	47·40	63·20	79·00	94·80	110·60	126·40	142·20	158·00	189·60	237·00
3250	50·40	67·20	84·00	100·80	117·60	134·40	151·20	168·00	201·60	252·00
3500	53·40	71·20	89·00	106·80	124·60	142·40	160·20	178·00	213·60	267·00
3750	56·10	74·80	93·50	112·20	130·90	149·60	168·30	187·00	224·40	280·50
4000	58·80	78·40	98·00	117·60	137·20	156·80	176·40	196·00	235·20	294·00
4250	60·33	80·44	100·55	120·66	140·77	160·88	180·99	201·10	241·32	301·65
4500	61·86	82·48	103·10	123·72	144·34	164·96	185·58	206·20	247·44	309·30
4750	64·29	85·72	107·15	128·58	150·01	171·44	192·87	214·30	257·16	321·45
5000	66·72	88·96	111·20	133·44	155·68	177·92	200·16	222·40	266·88	333·60

HORSE-POWER OF BALATA BELTING AT VARIOUS SPEEDS AND PLYS.

Horse-power Good Balata or Textile Belts should transmit at speeds given with arc of contact not less than 180°.

Speed of Belt per minute	3 Ply	4-Ply	5 Ply	6 Ply	7 Ply	8 Ply	9 Ply	10 Ply
Feet	H P. per in. of width	H P. per in of width	H P per in of width	H P per in. of width	H P per in. of width	H P per in of width	H P per in of width	H P. per in of width
500	·70	1·00	1·30	1·60	1·90	2·20	2·50	3·00
750	1·00	1·50	1·95	2·40	2·85	3 30	3 75	4·20
1000	1·35	1·95	2·60	3·20	3·80	4·40	5·00	5·60
1250	1·70	2·45	3·20	3·95	4·75	5·50	6·25	7·00
1500	2·05	2·95	3·85	4·75	5·70	6·60	7·50	8·40
1750	2·40	3·45	4·50	5·55	6·65	7·70	8·75	9·80
2000	2·75	3·95	5·15	6·35	7·60	8·80	10·00	11·20
2250	3·05	4·45	5·80	7·15	8·50	9 90	11·25	12·60
2500	3·40	4·95	6·45	7·95	9·45	11 00	12·50	14·00
2750	3·75	5·40	7·05	8·75	10·40	12·10	13·75	15·40
3000	4·10	5·90	7·75	9·55	11·35	13·20	15·00	16·80
3250	4·45	6·40	8·35	10·35	12·30	14·30	16·25	18·20
3500	4·75	6·90	9·00	11·15	13·25	15·40	17·50	19·60
3750	5·10	7·40	9·65	11·95	14·20	16·50	18·75	21·00
4000	5·45	7·90	10·30	12·75	15·15	17·60	20·00	22·45

Thickness of Belts suitable for various diameters of Pulleys.

Diameter of Smallest Pulley	3 in and under	Over 3 in to 4 in	Over 4 in to 12 in.	Over 12 in. to 16 in.	Over 16 in to 18 in.	Over 18 in. to 24 in.	Over 24 in. to 36 in.
Ply recommended ...	3	4	5	6	7	8 & 9	10
Approx. Thickness in.	3/16	7/32	1/4	5/16	3/8	7/16 & 1/2	9/16

Approximate weights in lb of various plys of Balata Belting per 100 ft of length.

Widths of Belt Ins.	3 Ply	4 Ply	5 Ply	6 Ply	7-Ply	8-Ply	10 Ply	Widths of Belt Ins.	3 Ply	4-Ply	5 Ply	6 Ply	7-Ply	8-Ply	10-Ply
1¼	9½	12						5	34	43	53	65			
1½	11½	15½						5½		48	58	69			
2	13½	16						6		52	62	74		97	
2¼	15	19						6½		57					
2½	16	21	25½					7	47	60	75	88	101		
2¾	18	24	27½					8		69	90	100	114	130	
3	20	25	31					9			100	115		150	
3½	26	30	37	41				10		84	110	127		166	
4	28	34	41	49				11½				142			
4¼	30	37	47					12			133	152	186	200	
4½		41													

APPROXIMATE CENTRE DISTANCE APART OF BEARINGS FOR SHAFTING CARRYING NORMAL LOADS.

(Messrs. Crofts, Bradford.)

TRANSMISSION SHAFTING—FOR TRANSMITTING POWER ONLY.

Approximate limit of distance apart of Centres of Bearings for Shafts which do *not* carry any Pulley Gears, etc.

Dia. of Shaft. in.	1½	1¾	2	2¼	2½	2¾	3	3¼	3½	4	4½	5	5½	6
Revs per Minute.	Distance between Bearing Centres in feet.													
100	9	10	11	11½	12	12½	13	13½	14	14½	15	16	17	18
150	8½	9½	10¾	11¼	11¾	12	12½	13	13½	14	14½	15½	16½	17½
200	8	9	10½	10¾	11¼	11½	12	12½	13	13½	13¾	14¾	15¾	16¾
250	7½	8½	10	10¼	10¾	11	11½	12	12¼	12¾	13¼	14	15	16
300	7	8	9½	9¾	10	10¼	10¾	11	11½	12	12½	13¼	14	15
350	6¾	7¾	8¾	9	9¼	9½	10	10½	10¾	11	11½	12¼	13	13¾
400	6¼	7¼	8	8¼	8½	9	9¼	9½	10	10¼	10½	11¼	12	12½
500	5¾	6¾	7½	7¾	8	8½	9	9¼	9½	9¼	10	10½	11	11½
600	5¼	6¼	7	7¼	7½	8	8½	9	9¼	9½	9¾	10	10½	11
700	4¾	5¾	6½	6¾	7	7½	8	8½	8¾	9	9½	9¾	10	
800	4½	5¼	6	6¼	6½	7	7½	8	8½	8¾	9	9¼		
1,000	4	4¾	5½	5¾	6	6½	7	7½	8					

LINE SHAFTING—CARRYING PULLEYS, ETC.

Approximate limit of distance apart of Centres of Bearings for Shafts which do not carry more than an average number of pulleys transmitting normal powers.

1½	1¾	2	2¼	2½	2¾	3	3¼	3½	4	4½	5	5½	6
Distance between Bearing Centres in feet.													
7¼	7½	8	8½	9	9½	10	10½	11	11½	12	13	14	15
6¾	7¼	7¾	8¼	8¾	9¼	9¾	10¼	10¾	11¼	11¾	12¾	13¾	14½
6½	7	7½	8	8½	9	9½	10	10½	11	11½	12¼	13¼	14
6	6¾	7¼	7¾	8¼	8¾	9¼	9¾	10	10½	11	11¼	12½	13¼
5¾	6½	7	7½	8	8½	8¾	9¼	9½	10	10½	11	11¾	12½
5¼	6	6¾	7¼	7¾	8	8½	8¾	9	9½	9¾	10¼	11	11½
5	5¾	6½	7	7½	7¾	8	8¼	8½	8¾	9	9½	10	10½
4½	5½	6¼	6½	7	7½	7¾	8	8¼	8¼	8¾	9¼	9½	10
4¼	5¼	6	6¼	6½	7	7¼	7½	8	8¼	8½	9	9¼	9½
4	4¾	5½	5¾	6	6½	7	7¼	7¾	8	8¼	8½	8¾	
3¾	4¼	5	5¼	5½	6	6½	7	7½	7¾	8	8¼		
3½	4	4½	4¾	5	5½	6	6½	7					

Power Required for Machine Tools

Kind of Machines.	Size.	Material Cut.	Number of Tools.	Horse Power.		
				Motor and Shaft.	Empty Machine.	Average Cutting.
				H.P.	H.P.	H.P.
Wheel lathe .	84 in.	Cast iron	2	—	—	6·1
,, ,, .	84 in.	,,	2	—	—	5·1
,, ,, .	84 in.	,,	2	—	1·5	5·8
Boring mill .	78 in.	,,	1	—	—	4·5
,, ,, .	76 in.	,,	1	—	—	6·5
Slotting machine	36in. × 12in.	Wro't iron	1	1·5	1·5	5·3
Sellers planer .	62in. × 35ft.	,,	2	4·4	11·4	21·1
,, ,, .	62in. × 35ft.	,,	2	—	5·8	24·5
Planer . .	36in. × 12ft.	,,	2	2·7	3·0	12·5
Bement planer .	24in. × 13ft.	Steel	2	1·95	4·3	8·0
Sellers planer .	36in. × 18ft.	Wro't iron	2	3·2	4·3	16·7
,, ,, .	56in. × 35ft.	,,	2	4·6	9·9	13·3
,, ,, .	56in. × 24ft.	,,	2	4·56	6·0	16·8
Wheel lathe .	90 in.	Cast steel	2	1·43	2·1	6·34
Bement drill .	21 ft.	Wro't iron	3-⅞in.	2·1	2·6	4·2
,, ,, .	21 ft.	,,	3-2in.	2·1	2·6	8·0
Harrington drill .	22 ft.	,,	2-1in.	1·1	1·45	3·7
Radial drill. .	42 in.	,,	1-2in.	0·96	1·1	2·1
Boring mill .	4 ft. 6 in.	Cast steel	1	2·1	2·4	4·6
,, ,, .	5 ft. 6 in.	Cast iron	1	1·6	2·4	4·4
Slotting machine	40in. × 15in.	Wro't iron	1	1·8	2·2	7·3
Shaping machine	19 in. stroke	,,	1	1·6	1·8	7·3

CONVERSION OF POWER

	Horse power to Kilowatts.	Kilowatts to Horse power.	Metric Horse power to Kilowatts.	Kilowatts to Metric Horse power.	Horse power to Metric Horse power.	Metric Horse power to Horse power.
1	0·7457	1·341	0·7354	1·360	1·014	0·9863

CHAIN SLINGS.

Chain Diameter. Ins.	Safe Working Loads in Tons and Cwts. for given Angles between Legs.					
	0°	30°	60°	90°	120°	150°
	Tons Cwts.	Tons Cwts.	Tons Cwts.	Tons Cwts.	Tons Cwts.	Tons Cwts.
3/16	0–8	0–8	0–7	0–5	0–4	0–2
1/4	0–15	0–14	0–13	0–10	0–7	0–3
5/16	1–3	1–2	1–0	0–16	0–11	0–5
3/8	1–13	1–12	1–9	1–3	0–16	0–8
1/2	3–0	2–17	2–12	2–2	1–10	0–15
5/8	4–13	4–10	4–0	3–6	2–6	1–4
3/4	6–15	6–10	5–17	4–15	3–7	1–14
7/8	9–3	8–17	7–18	6–9	4–11	2–7
1	12–0	11–11	10–7	8–9	6–0	3–1
1 1/8	15–3	14–12	13–2	10–14	7–11	3–18
1 1/4	18–15	18–2	16–5	13–5	9–7	4–16
1 3/8	22–13	21–17	19–12	16–0	11–7	5–17
1 1/2	27–0	26–1	23–8	19–1	13–0	6–19
1 5/8	31–12	30–12	27–8	22–8	15–16	8–3
1 3/4	36–15	35–9	31–16	25–19	18–7	9–9
1 7/8	42–3	40–14	36–10	29–16	21–1	10–17
2	48–0	46–8	41–11	33–18	24–0	12–7
2 1/8	54–2	52–6	46–18	38–5	27–1	13–19
2 1/4	60–15	58–12	52–12	42–19	30–7	15–13
2 3/8	67–12	65–6	58–12	47–16	33–16	17–8
2 1/2	75–0	72–9	65–0	53–0	37–10	19–7

ANALYSES OF VARIOUS LIQUID FUELS.

With Calorific Value, Specific Gravity, Flash Point, and Ignition Point.

Kind of Fuel.	British Mexican Boiler Oil.	Borneo.	Texas.	California.	Rou-manian.	Anglo-Persian Diesel Oil.
Carbon . . .	82·80	86·74	86·30	84·43	87·11	84·66
Hydrogen . .	11·23	10·67	12·22	10·99	11·87	12·4
Sulphur . .	3·73	0·03	1·33	0·59	0·16	1·3
Nitrogen . .	0·31	0·05	0·06	0·65	0·15	0·16
Oxygen Water Ash	3·95	2·51	0·09	3·34	0·71	1·63
Calorific Value in B.Th.U. . .	18,250	18,830	18,400	18,806	19,320	19,150
Specific Gravity at 60° F. . .	0·95	0·9628	0·922	0·962	0·935	0·902
Flash Point . .	165°F.	225°F.	160°F.	228°F.	244°F.	173°F.
Ignition Point .	184°F.	294°F.	215°F.	258°F.	298°F.	192°F.

From an average analysis the following quantities have been calculated in respect of the perfect combustion of 1 lb. of fuel:

CO_2	Steam.	SO_2	O_2	Air Required.
3·08	1·07	0·51	3·21	13·85 lb.

One barrel of oil contains approx. 41 gallons.

1 ton of oil, 0·98 sp. gr. requires 39 cub. ft.

Wt. of water evaporated/lb. of oil burned 14 to 15 lb.

CUTTING LUBRICANTS.

Use Soapy Compound for Turning and Drilling Mild Steel and Wrought Iron.

Use Lard Oil for Reaming and Tapping Steel and Wrought Iron and for Broaching.

Use Paraffin Oil for Turning, Tapping, and Reaming Aluminium.

Use a drip of petroleum (two parts) and turpentine (one part). This will ensure easy cutting and perfect tools when otherwise the work of turning hard metals would stop owing to breakage of tools from severe strain. Turpentine has been used alone with quite good results.

In the tool room nitric acid is used for marking hard steel tools and gauges. This acid has also been used to drill holes in hardened steel. In both cases the steel is covered with melted bees' wax. When coated and cold make a hole the required size in the wax or print the marking required with a fine pointed needle. Put a drop of strong nitric acid upon it and after an hour rinse it off. In the case where a hole is required, apply again and the acid will gradually eat through the hardened steel.

PROPERTIES OF ALUMINIUM.

(The British Aluminium Co.)

Property	Value	Authority
PHYSICAL CONSTANTS		
Atomic Weight (Oxygen = 16)	26·97	Int. Atomic Wt. Comm., 1929
Spec. Ht., 20°–400° C. (av.) cals.	0·24	Int. Crit. Tables Formula.
Spec. Thermal Conductivity in cals. per cm. cube per degree C. per sec., at 0° C.	0·502	Bailey, Proc. Roy. Soc. A., 134, 57–76, 1931.
Approx. Relative Heat Conductivity (Silver = 100%)	51·8	
Melting Point (99·97% pure) °C.	659·8	Edwards, J., American Electrochem. Soc., 1925.
,, ,, (99·66% pure) °C.	658·7	
Boiling Point, °C.	1800	Greenwood, Proc. Royal Soc. 82, 1909.
Latent Ht. of Fusion, cals per gm.	92·4	Awbery & Griffiths, Proc. Phys. Soc., Lond., Vol. 38, pt. 5, Aug. 15, 1926.
Total Ht. referred to 20° C., calories per gm. 400° C.	88	
,, ,, 600° C.	140	
,, ,, 700° C.	267	
Vapour Pressure at 658·7° C., mm. of Mercury	$1{\cdot}0 \times 10^{-43}$	Richards, Jour. Franklin Inst., Vol. 187, 1919.
Heat of Combustion to Al_2O_3 per gm. mol., cals.	383,900	A.S.S.T. Handbook.
Coeff. of Linear Expansion /°C.		
H.D. Wire (99·6% pure) at 15°C.	23×10^{-6}	Int. Electrotech. Comm.
Rolled Metal (99·15% pure), Average value, 20°–100° C.	24×10^{-6}	Based on Hidnert, U.S. Bureau of Standards Paper No. 497.
,, ,, 20°–300° C.	$26{\cdot}7 \times 10^{-6}$	
,, ,, 20°–10° C.	$28{\cdot}6 \times 10^{-6}$	
Specific Gravity:		
Rolled or Drawn (high purity)	2·703	B.S.S. No. 215, 1934.
,, ,, (normal purity)	2·71	British Aluminium Co. Ltd.
Molten (high purity), 658·7° C.	2·382	Edwards & Moorman, Chem. Met. Eng., Vol. 24, pp. 61–64, 1921.
,, (high purity), 1100° C.	2·262	
Wt. of 1 cubic ft. of Aluminium, (normal purity), lb.	169·18	Calculated from Specific Gravity.
Wt. of 1 cubic ft. of Aluminium, (high purity), lb.	168·74	
MECHANICAL CONSTANTS		
Modulus of Elasticity, lb./sq. in.	$9{\cdot}9 \times 10^{6}$	B.S.S. No. 215, 1934.
Torsion Modulus, lb./sq. in.	$3{\cdot}87 \times 10^{6}$	Koch & Dannecker, Ann. d. Phys., 1915.
Poisson's Ratio	·36	Bureau of Standards, Circ. No. 76, 1919.

PROPERTIES OF DURALUMIN.

(The British Aluminium Co.)

Chemical Composition	Copper	between 3·5 and	4·5%
	Manganese	„ 0·4 „	0·7%
	Magnesium	„ 0·4 „	0·7%
	Iron	not more than	0·75%
	Aluminium about		94·5%
Specific Gravity	2·79		
Specific Heat	0·214 (Water = 1)		
Thermal Conductivity	31 (Silver = 100)		
Electrical „	Normalised 33 to 35% Annealed 39 to 41%		
Co-efficient of Linear Expansion (20° to 100°C.)	·000023 per ° C.		
Young's Modulus (E)	10×10^6 lb. per square inch		
Melting Range	560° to 650° C.		
Annealing Range	360° to 400° C.		
Heat-treating or Normalising Temperature	490° ± 5° C.		
Forging or Hot Stamping Temperature	400° to 470° C.		
Time for Ageing	Not less than three days at room temperature		
Weight	175·3 lb. per cubic foot 0·101 lb. per cubic inch		
Brindell Hardness	Annealed Material, 60 Normalised „ 90 to 110		

Mechanical properties of Heat-treated and aged Material.

Material.		0·1% Proof Stress.	Maximum Stress.	Elongation per cent. in 2 in.	Reduction of area per cent.
		Tons per sq. inch.			
Sheet .	·048″ and up .	15	5	15	—
	·02″ to ·048″ . .	15	25	12	—
	below ·02″ . .	15	25	8	—
Tubes .	·104″ thick and up .	18	26	12·5	—
	·064″ to ·104″ .	18	26	10	—
	·064″ & under .	18	26	8	—
Bars . .	Up to 2⅝″ dia. .	15	25	15	20
	2⅝″ to 4″ . .	12	22	15	20
	4″ to 6″ . .	10	20	15	20
Stampings .	—	15	25	15	20
Rivets .	—	—	16 (Single Shear)	—	—
Annealed Sheet or Bar . .		10	15	20	—

PROPERTIES OF ALUMINIUM-MAGNESIUM ALLOYS.

(The British Aluminium Co.)

Specific gravity	2·68
Young's Modulus	10 x 10^6 lb./sq. in.
Casting range	665° to 720° C.
Annealing Range	400° to 440° C.
Weight	167·3 lb./cu. ft.
,,	0·097 lb./cu. in.
Coefficient of Linear Expansion (extruded material)	·000023 per 1° C. between 0° and 32° C.
Fatigue Range:	
Sand Cast	± 4·75 tons/sq. in.
Chill Cast	± 6·8 tons/sq. in.
Extruded Bar	± 8·3 tons/sq. in.
Maximum Sheer Stress:	
Rivets	10·5/11·5 tons/sq. in.
Hard Sheets	15·8/16·2 tons/sq. in.

General Form.	Particular Form.		0.1% Proof Stress.	Maximum Stress.	Elongation % in 2 in.	Brinell Hardness No.
			Tons per sq in.			
Castings .	Chill cast bars		6 7	13 15	10–15	58
	Sand cast bars		5-6½	9 10	3-5½	54
Extrusions .	Sections		9–11	15–19	15–25	60
Sheets .	Light Gauge	Hard	—	23–24	4-5	89
		Soft	6–8	15–17	22–24	—
	Medium Gauge	Hard	15–20	22–23	6–7	86
		Soft	6–8	15–16	22–24	58–64
	Plates $\frac{3}{16}$-in. thick and heavier	Hard	14–16	19½–20½	7–9	80–84
		Soft	6 8	15–16	22-26	58–64
Tubing .	Various Sections	Hard	—	23 24	3·5–4	95
		Soft	6–8	15-16	22–26	53–58
Drawn Wire			15–20	20–25	6–9	70–80

Specially ductile and high tensile wrought forms of **Birmabright** are also available.

BRITISH STANDARD TABLES OF PIPE FLANGES (FOR LAND USE).

FLANGES FOR PIPES, VALVES, AND FITTINGS, for Working Steam Pressures up to 50 lbs. per Square Inch.

1	1 (a)	2	3	4	5	6 (a)	6 (b)	6 (c)
						Thickness of Flange.		
Nominal Pipe Size.	Actual Outside Diameter of Wrought Pipe.	Diameter of Flange.	Diameter of Bolt Circle.	Number of Bolts.	Diameter of Bolts	Cast Iron.	Cast Steel and Bronze.	Iron or Steel (stamped or forged), screwed or riveted on with boss, or welded on with fillet.
in.	in.	in.	in.		in.	in.	in.	in.
½	27/32	3¾	2⅝	4	½	½	⅜	3/16
¾	1 1/16	4	2⅞	4	½	½	⅜	3/16
1	1 11/32	4½	3¼	4	½	½	⅜	3/16
1¼	1 11/16	4¾	3 7/16	4	½	⅝	½	¼
1½	1 29/32	5¼	3⅞	4	½	⅝	½	¼
2	2⅜	6	4½	4	⅝	¾	9/16	5/16
2½	3	6½	5	4	⅝	¾	9/16	5/16
3	3½	7¼	5¾	4	⅝	¾	9/16	⅜
3½	4	8	6½	4	⅝	¾	9/16	⅜
4	4½	8½	7	4	⅝	⅞	11/16	⅜
*4½	5	9	7½	8	⅝	⅞	11/16	7/16
5	5½	10	8¼	8	⅝	⅞	11/16	½
6	6½	11	9¼	8	⅝	⅞	11/16	½
7	7½	12	10¼	8	⅝	1	¾	½
8	8½	13¼	11½	8	⅝	1	¾	½
9	9½	14½	12¾	8	⅝	1	¾	⅝
10	10½	16	14	8	¾	1	¾	⅝
*11	11½	17	15	8	¾	1⅛	⅞	⅝
12	12½	18	16	12	¾	1⅛	⅞	⅝
*13	14	19¼	17¼	12	¾	1⅛	⅞	¾
14	15	20¾	18½	12	⅞	1¼	1	¾
15	16	21¾	19½	12	⅞	1¼	1	¾
16	17	22¾	20½	12	⅞	1¼	1	¾
*17	18	24	21¾	12	⅞	1⅜	1⅛	⅞
18	19	25¼	23	12	⅞	1⅜	1⅛	⅞
*19	20	26½	24	12	⅞	1⅜	1⅛	⅞
20	21	27¾	25¼	16	⅞	1½	1¼	1
21	22	29	26½	16	⅞	1½	1¼	1
*22	23	30	27½	16	1	1½	1¼	1
*23	24	31	28½	16	1	1⅝	1⅜	1⅛
24	25	32½	29¾	16	1	1⅝	1⅜	1⅛

* The Association recommends that the use of these sizes be avoided.

THICKNESS.—The thicknesses given in this Table include a raised face of not more than 1/16 in. high, if such be used.

BOLT HOLES.—For ½ in. and ⅝ in. bolts the diameters of the holes to be 1/16 in. larger than the diameter of the bolts, and for larger sizes of bolts ⅛ in. Bolt holes to be drilled off centre lines.

BRITISH STANDARD TABLES OF PIPE FLANGES (FOR LAND USE).

Flanges for Pipes, Valves, and Fittings,

For Working Steam Pressures above 50 lbs. and up to 100 lbs. per Square Inch.

1	1 (a)	2	3	4	5	6 (a)	6 (b)	6 (c)
						Thickness of Flange.		
Nominal Pipe Size.	Actual Outside Diameter of Wrought Pipe.	Diameter of Flange.	Diameter of Bolt Circle.	Number of Bolts.	Diameter of Bolts.	Cast Iron.	Cast Steel and Bronze.	Iron or Steel (stamped or forged), screwed or riveted on with boss, or welded on with fillet.
in.	in.	in	in.		in.	in.	in.	in.
½	27/32	3¾	2⅝	4	½	½	⅜	¼
¾	1 1/16	4	2⅞	4	½	½	⅜	¼
1	1 11/32	4½	3¼	4	½	½	⅜	9/32
1¼	1 11/16	4¾	3 7/16	4	½	⅝	½	5/16
1½	1 29/32	5¼	3⅞	4	½	⅝	½	11/32
2	2⅜	6	4½	4	⅝	¾	9/16	¾
2½	3	6½	5	4	⅝	¾	9/16	13/32
3	3½	7¼	5¾	4	⅝	¾	9/16	7/16
3½	4	8	6½	8	⅝	¾	9/16	15/32
4	4½	8½	7	8	⅝	⅞	11/16	½
*4½	5	9	7½	8	⅝	⅞	11/16	½
5	5½	10	8¼	8	⅝	⅞	11/16	9/16
6	6½	11	9¼	8	¾	⅞	11/16	11/16
7	7½	12	10¼	8	¾	1	¾	¾
8	8½	13¼	11½	8	¾	1	¾	¾
9	9½	14½	12¾	12	¾	1	13/16	13/16
10	10½	16	14	12	¾	1	⅞	⅞
*11	11½	17	15	12	¾	1⅛	15/16	15/16
12	12½	18	16	12	⅞	1⅛	1	1
*13	14	19¼	17¼	12	⅞	1⅛	1	1
14	15	20¾	18½	12	⅞	1¼	1	1
15	16	21¾	19½	12	⅞	1¼	1	1
16	17	22¾	20½	12	⅞	1¼	1	1
*17	18	24	21¾	12	⅞	1⅜	1⅛	1⅛
18	19	25¼	23	16	⅞	1⅜	1⅛	1⅛
*19	20	26½	24	16	⅞	1⅜	1¼	1¼
20	21	27¾	25¼	16	⅞	1½	1¼	1¼
21	22	29	26½	16	1	1½	1⅜	1⅜
*22	23	30	27½	16	1	1½	1⅜	1⅜
*23	24	31	28½	16	1	1⅝	1⅜	1⅜
24	25	32½	39¾	16	1	1⅝	1½	1½

* The Association recommends that the use of these sizes be avoided.

Thicknesses.—The thicknesses given in this Table include a raised face of not more than 1/16 in high, if such be used.

Bolt Holes.—For ½ in. and ⅝ in bolts the diameters of the holes to be 1/16 in. larger than the diameter of the bolts, and for larger sizes of bolts ⅛ in. Bolt holes to be drilled off centre lines.

Thermal Properties of Solids.

	Density Grammes per cc.	Density Lbs. per Cub. Ft.	Specific Heat.	Melting Point ° F.	Latent Heat.		Coefficient of Linear Expansion per °F. — 10^{-4}.	Thermal Conductivity.	
					Calories per Gram.	B.Th.U. per Lb.		C.G.S. °C. Units	B.Th.U./sq. ft./deg. F./in./hr.
Aluminium	2·6	162	·219	1220	107	193	·128	·3435	996·8
Antimony	6·6	410	·0507	1166	—	—	·064	·0442	128·2
Bismuth	9·8	609	·0298	520	12·5	22·7	·075	·0177	51·36
Brass	8·2 to 8·7	510 to 540	·092	1832	—	—	·104	·2041	592·2
Copper	8·9	552	·0936	1981	43	72·5	·093	·7198	2088·
Graphite	1·9 to 2·3	118 to 143	·2	6332	—	—	·044	·00043	1·247
German silver	8·3 to 8·8	515 to 545	·0946	1996	—	—	·102	·0700	203·1
Glass (crown)	2·5 to 2·7	155 to 168	·161	2012	—	—	·050	·00163	4·730
,, (flint)	3·0 to 3·6	186 to 224	·117				·044	·00143	4·149
Gold	19·3	1200	·0316	1946	—	—	·080	·7003	2032·
Indiarubber	·92 to ·99	57·0 to 61·5	·48	—	—	—	·390	·0004	1·16
Iron (cast)	7·0 to 7·7	435 to 478	·114	Grey 2010–2190 White 1920–2010	23 33	41 59	·059	·1665	483·1
,, (wrought)	7·8 to 7·9	485 to 490	·109	2950	—	—	·069	·2070	600·7
Steel	7·8	485	·117	2370 to 2550	—	—	Soft ·065 Hard ·078	—	—
Lead	11·4	712	·0305	621	5·4	10·6	·163	·0836	242·6
Nickel	8·9	553	·109	2646	4·6	8·3	·071	·1402	406·8
Platinum	21·5	1335	·0324	3223	27·2	48·9	·050	·1699	493·
Silver	10·5	655	·0559	1760	21·1	38	·106	1·096	3180·
Tin	7·3	454	·0553	449	14·1	24	·124	·1528	443·4
							Parallel to fibre. Across fibre.		
Wood (Oak)	·6 to ·9	37 to 56	—	—	—	—	·027 ·302	·0006	1·741
,, (Pine)	·4 to ·8	25 to 50	—	—	—	—	·030 ·189	·0003	·8706
Zinc	7·1	441	·935	812	28	50·6	·162	·2636	764·9

PHYSICAL PROPERTIES OF VARIOUS METALS

Metal.	Atomic Weight. O = 16	Specific Gravity.	Weight per cu. in. lb.	Melting Point. °C.	Thermal Conductivity. Cals./cm. ^{1}/°C. per. sec.	Specific Heat Cals. per gm. per °C.
Aluminium (H.D. wire)	27.1	2.703	.0975	658.7	.504	.214
Antimony	120.2	6.71	.242	630	.044	.051
Bismuth	208	9.9	.357	271	.019	.031
Cadmium	112.4	8.65	.311	321	.222	.057
Cobalt	58.97	8.6	.310	1490	—	.107
Copper (H.D. wire)	63.6	8.89	.320	1083	.89	.097
Gold (wrt.)	197.2	19.4	.700	1063	.70	.032
Iron (cast)	—	7.22 (av.)	.260	1375	.161	.125
,, (wrt.)	55.84	7.70 (av.)	.278	1550 (av.)	.144	.114
Lead	207.2	11.4	.411	327	.083	.031
Magnesium	24.32	1.74	.0627	651	.376	.250
Mercury	200.6	13.59	.490	—38.7	.0197	.033
Nickel	58.68	8.67	.312	1452	.142	.109
Palladium	106.7	11.4	.411	1549	.168	.052
Platinum (wrt.)	195.2	22.1	.797	1755	.166	.032
Silver (wrt.)	107.88	10.5	.378	961	1.006	.056
Steel (wire)	—	7.84	.282	1350 (av.)	.115	.117
Tantalum (wire)	181.5	16.6	.598	1850	—	.036
Tin (cast)	118.7	7.29	.263	232	.155	.054
Tungsten (wire)	184	19.1	.689	3000	—	.033
Zinc (sheet)	65.37	7.19	.259	419	.265	.092

CONVERSION TABLES FOR DIAMETRAL, CIRCULAR AND MODULE PITCHES

Circular Pitch Inches	Diametral Pitch
4	·7854
3½	·8976
3	1·0472
2¾	1·1424
2½	1·2566
2¼	1·3963
2	1·5708
1⅞	1·6755
1¾	1·7952
1⅝	1·9333
1½	2·0944
1⅜	2·2548
1¼	2·5133
1⅛	2·7925
1	3·1416
15/16	3·3510
⅞	3·5904
13/16	3·8666
¾	4·1888
11/16	4·5696
⅝	5·0265
9/16	5·5851
½	6 2832
7/16	6·1808
⅜	8·3776
5/16	10·0531
¼	12·5664

Diametral Pitch.	Circular Pitch Inches.
20	·1571
19	·1653
18	·1745
17	·1848
16	·1963
15	·2094
14	·2244
13	·2416
12	·2618
11	·2856
10	·3142
9	·3491
8	·3927
7	·4488
6	·5236
5	·6283
4	·7854
3½	·8976
3	1·0472
2¾	1·1424
2½	1·2566
2¼	1·3963
2	1·5708
1¾	1·7952
1½	2·0944
1¼	2·5133
1	3·1416

Module Pitch M/m.	Circular Pitch M/m	English Diametral Pitch.
·5	1·57	50·800
·75	2·35	33·866
1·0	3·14	25·400
1·25	3·93	20·320
1·5	4·71	16·933
1·75	5·5	14·514
2·0	6·28	12·700
2·25	7·07	11·288
2·5	7·86	10·160
2·75	8·63	9·236
3·0	9·42	8·466
3·25	10·2	7·81
3·5	11·0	7·257
3·75	11·77	6·773
4·0	12·57	6·350
4·25	13·35	5·708
4·5	14·14	5·644
5·0	15·71	5·080
5·5	17·28	4·618
6·0	18·86	4·233
6·5	20·41	3·907
7·0	22·0	3·628
8·0	25·14	3·175
9·0	28·27	2·822
10·0	31·41	2·540
11·0	34·56	2·309
12·0	37·7	2·117

BRITISH STANDARD WHITWORTH BOLTS AND NUTS (BLACK)

Size of Bolt and Thickness of Nut.	No. of Threads per inch.	Core Diameter.	Thickness of Bolt Head Max.	Nut Across Flats Max.	Nut Across Corners.	Tap Drill Size.
in.		in.	in.	in.	in.	in.
$\frac{1}{4}$	20	.1860	.24	.525	.61	$\frac{3}{16}$
$\frac{5}{16}$	18	.2414	.29	.60	.69	$\frac{1}{4}$
$\frac{3}{8}$	16	.2950	.35	.710	.82	$\frac{19}{64}$
$\frac{7}{16}$	14	.346	.40	.820	.95	$\frac{11}{32}$
$\frac{1}{2}$	12	.3933	.46	.920	1.06	$\frac{25}{64}$
$\frac{9}{16}$	12	.4558	.51	1.010	1.17	$\frac{29}{64}$
$\frac{5}{8}$	11	.5086	.57	1.100	1.27	$\frac{33}{64}$
$\frac{11}{16}$	11	.5711	.62	1.200	1.39	$\frac{37}{64}$
$\frac{3}{4}$	10	.6219	.68	1.300	1.50	$\frac{41}{64}$
$\frac{13}{16}$	10	.6844	.73	1.390	1.61	$\frac{11}{16}$
$\frac{7}{8}$	9	.7327	.79	1.480	1.71	$\frac{47}{64}$
$\frac{15}{16}$	9	.7952	.84	1.580	1.82	$\frac{51}{64}$
1	8	.8399	.90	1.670	1.93	$\frac{27}{32}$
$1\frac{1}{8}$	7	.942	1.01	1.860	2.15	$\frac{15}{16}$
$1\frac{1}{4}$	7	1.067	1.12	2.050	2.37	$1\frac{1}{16}$
$1\frac{3}{8}$	6	1.1616	1.23	2.220	2.56	$1\frac{5}{32}$
$1\frac{1}{2}$	6	1.2866	1.34	2.410	2.78	$1\frac{9}{32}$
$1\frac{5}{8}$	5	1.3689	1.45	2.580	2.98	$1\frac{3}{8}$
$1\frac{3}{4}$	5	1.4939	1.56	2.760	3.19	$1\frac{1}{2}$
$1\frac{7}{8}$	$4\frac{1}{2}$	1.5904	1.67	3.020	3.49	$1\frac{19}{32}$
2	$4\frac{1}{2}$	1.7154	1.78	3.150	3.64	$1\frac{23}{32}$
$2\frac{1}{4}$	4	1.9298	2.00	3.550	4.10	$1\frac{15}{16}$
$2\frac{1}{2}$	4	2.1798	2.22	3.890	4.49	$2\frac{3}{16}$
$2\frac{3}{4}$	$3\frac{1}{2}$	2.3841	2.44	4.180	4.83	$2\frac{25}{64}$
3	$3\frac{1}{2}$	2.6341	2.66	4.530	5.23	$2\frac{41}{64}$

NOTE.—Square Nuts across Flats, same as Hexagon.

CONVERSION OF AREAS.

	Sq. in. to sq. cm.	Sq. cm. to sq. in.	Sq. ft. to sq. m.	Sq. m. to sq. ft.	Sq. yd. to sq. m.
1.	6.452	0.1550	0.0929	10.76	0.8361
	Sq. m. to sq. yd.	**Acres to hectares.**	**Hectares to acres**	**Sq. mi. to sq. km.**	**Sq. km. to sq. mi.**
1.	1.196	0.4947	2.471	2.590	0.3861

BRITISH STANDARD FINE SCREW THREADS

Full Diameter.	No. of Threads per in.	Core Diameter.	Nut across Flats.	Tap Drill Size.
in.		in.	in.	
3/16	32	·1475	—	25
7/32	28	·1731	·413	15
1/4	26	·2007	·445	13/64 in.
9/32	26	·2320	·525	15/64 ,,
5/16	22	·2543	·525	17/64 ,,
3/8	20	·3110	·60	5/16 ,,
7/16	18	·3664	·71	3/8 ,,
1/2	16	·4200	·82	27/64 ,,
9/16	16	·4825	·92	31/64 ,,
5/8	14	·5335	1·010	35/64 ,,
11/16	14	·5960	1·100	39/64 ,,
3/4	12	·6433	1·200	21/32 ,,
7/8	11	·7586	1·300	49/64 ,,
1	10	·8719	1·480	7/8 ,,
1 1/8	9	·9827	1·670	63/64 ,,
1 1/4	9	1·1077	1·860	1 7/64 ,,
1 3/8	8	1·2149	2·050	1 7/32 ,,
1 1/2	8	1·3399	2·220	1 11/32 ,,
1 5/8	8	1·4649	2·410	1 15/32 ,,
1 3/4	7	1·5670	2·580	1 37/64 ,,
2	7	1·8170	2·760	1 53/64 ,,
2 1/4	6	2·0366	3·150	2 9/64 ,,
2 1/2	6	2·2866	3·550	2 19/64 ,,
2 3/4	6	2·5366	3·890	2 35/64 ,,
3	5	2·7439	4·190	2 3/4 ,,

BRITISH AND WHITWORTH STANDARD THREADS FOR GAS AND WATER PIPES

Nominal Internal Diameter of Pipe.	British Standard.		Whitworth.		No. of Threads per in.
	Outside Diameter.	Core Diameter.	Outside Diameter.	Core Diameter.	
in.	in.	in.	in.	in.	
1/8	·383	·337	·3825	·3367	28
1/4	·518	·451	·518	·4506	19
3/8	·656	·589	·6563	·5889	19
1/2	·825	·734	·8257	·7342	14
5/8	·902	·811	·9022	·8107	14
3/4	1·041	·95	1·041	·9495	14
7/8	1·189	1·098	1·189	1·0975	14
1	1·309	1·193	1·309	1·1925	11
1 1/4	1·65	1·534	1·65	1·5335	11
1 1/2	1·882	1·766	1·882	1·766	11
1 3/4	2·116	2·0	2·047	1·9305	11
2	2·347	2·231	2·347	2·2305	11
2 1/4	2·587	2·471	2·587	2·471	11
2 1/2	2·96	2·844	3·001	2·8848	11
2 3/4	3·21	3·094	3·247	3·1305	11
3	3·46	3·344	3·485	3·3685	11
3 1/4	3·7	3·584	3·698	3·582	11
3 1/2	3·95	3·834	3·912	3·7955	11
3 3/4	4·2	4·084	4·125	4·009	11
4	4·45	4·334	4·339	4·2225	11

All threads on this page are Whitworth Form.

LARGE PIPES, BRITISH STANDARD
up to 6 in. 11 threads per inch
7 ,, 10 ,, 10 ,, ,, ,,
11 ,, 18 ,, 8 ,, ,, ,,
Whitworth Standard up to 12 in., 11 threads per inch.

MONEL METAL—MECHANICAL PROPERTIES

Type.	Condition.	Ultimate Strength. Tons/sq.in.	Yield Point. Tons/sq.in.	% Elongation. On $4\sqrt{\text{area}}$.	Hardness.
Hot Rolled Rounds, Squares, Rectangles or Hexagon: Forgings	Normal	34–38	15–18	35	120–140 Brinell
Cold Drawn Rounds or Hexagons: Cold Rolled Squares or Rectangles	(A) Hard	40–45	35–40	18–20	190–210 Brinell
	(A) Annealed	30–35	14–17	35	110–120 Brinell
Full Finish Sheet	Normal	30–33	14–16	30	18–20 Scleroscope
Cold Rolled Sheet or Strip	(A) Hard	45–50	40–45	15	38–42 Scleroscope
	(A) Annealed	29–30	14–16	30	16–18 Scleroscope
Cold Drawn Wire	(A) Hard for Springs	55–60	50–55	5–10	—
	(A) Annealed	29–33	14–16	35	—
Castings: Normal Quality	As Cast	19–23	12–15	12	110–130 Brinell
Special Silicon Quality	Thermally Hardened	38–40	22–25	10–15	190–120 Brinell

Note.—Monel Metal cannot be hardened by thermal treatment. Its mechanical properties can, however, be considerably enhanced by cold working, and for certain purposes it is definitely advantageous to employ it in a hard rolled or hard drawn condition. The mechanical properties of the hard rolled or soft annealed qualities in various forms are tabulated for guidance.

B.A. THREADS.

No.	Diameter.		Pitch.		Depth of Thread m.m.	Area at bottom of Thread sq. m m.	Tapping.		
							Core Diam.		Drill No.
	m.m.	in.	m m.	in.			m.m.	in.	
0	6·0	·236	1·00	·0394	·6	18·10	4·8	·189	12
1	5·3	·209	·90	·0354	·54	13·99	4·22	·166	19
2	4·7	·185	·81	·0319	·485	10·93	3·73	·147	26
3	4·1	·161	·73	·0287	·44	8·14	3·22	·127	31
4	3·6	·142	·66	·0260	·395	6·20	2·81	·111	34
5	3·2	·126	·59	·0232	·355	4·87	2·49	·098	40
6	2·8	·110	·53	·0209	·32	3·66	2·16	·085	44
7	2·5	·098	·48	·0189	·29	2·89	1·92	·076	48
8	2·2	·087	·43	·0169	·26	2·22	1·68	·066	51
9	1·9	·075	·39	·0154	·235	1·61	1·43	·057	53
10	1·7	·067	·35	·0138	·21	1·29	1·28	·050	56
11	1·5	·059	·31	·0122	·185	1·00	1·13	·044	59
12	1·3	·051	·28	·0110	·17	·72	·96	·038	62
13	1·2	·047	·25	·0098	·15	·64	·90	·035	65
14	1·0	·039	·23	·0091	·14	·41	·72	·028	70
15	·90	·035	·21	·0083	·125	·33	·65	·025	72
16	·79	·031	·19	·0075	·115	·25	·56	·022	74
17	·70	·028	·17	·0067	·10	·20	·50	·020	76
18	·62	·024	·15	·0059	·09	·15	·44	·017	77
19	·54	·021	·14	·0055	·085	·11	·37	·015	78
20	·48	·019	·12	·0047	·07	·091	·34	·013	80
21	·42	·017	·11	·0043	·065	·066	·29	·011	—
22	·37	·015	·10	·0039	·06	·049	·25	·010	—
23	·33	·013	·09	·0035	·055	·038	·22	·009	—
24	·29	·011	·08	·0031	·05	·028	·19	·008	—
25	·25	·010	·07	·0028	·04	·023	·17	·007	—

CONVERSION OF ENERGY, WORK, HEAT.

	Ft.-lb. to kilogrammetres.	Kilogrammetres to ft.-lb.	Ft.-lb. to B.T.U.	B.T.U. to ft.-lb.	Kilogrammetres to large calories.	Large calories to kilogrammetres.	Joules to small calories.	Small calories to joules.
1	0·1383	7·233	0·001286	777·5	0·002344	426·6	0·2390	4·183

Table of Threads for British Standard Copper Tubes.

Bore of Tube in.	Thickness, S.W.G.		Threads per in.
	Low Pressure.	Medium Pressure.	
⅛	16	16	28
¼	15	14	20
⅜	15	14	20
½	15	14	20
⅝	15	14	20
¾	15	13	20
⅞	15	13	20
1	14	12	20
1¼	14	12	20
1½	14	12	20
1¾	13	12	16
2	13	12	16
2¼	13	11	16
2½	13	11	16
2¾	13	10	16
3	12	10	16

Table of Threads for High Pressure Copper Tubes.

Bore of Tube in.	Thickness S.W.G.	Threads per in.
⅛	14	28
¼	13	19
⅜	13	19
½	12	14
⅝	11	14
¾	11	14
⅞	11	14
1	10	11
1⅛	9	11
1¼	9	11
1⅜	9	11
1½	9	11
1⅝	9	11
1¾	9	11
1⅞	9	11
2	9	11
2¼	8	11
2½	7	11

WHITWORTH STANDARD SCREW THREADS

For Small Size Bolts

Diam. of Bolt in. ...	1/16	3/32	⅛	5/32	3/16	7/32
No. of Threads per in. ...	60	48	40	32	24	24
Core Diam. in.	·0411	·0670	·0929	·1163	·1341	·1655
Tap Drill size gauge or in.	57	50	3/32	31	29	18

CONVERSION OF VOLUMES OR CAPACITIES.

	Liquid ounces to cu. cm.	Cu. cm. to liquid ounces.	Pints to litres.	Litres to pints.	Quarts to litres.
1.	29·57	0·03381	0·4732	2·113	0·9464
	Litres to quarts.	Gallons to litres.	Litres to gallons.	Bushels to hectolitres.	Hectolitres to bushels.
1.	1·057	3·785	0·2642	0·3524	2·838

FORMULÆ FOR M/CUT GEAR WHEEL TEETH

Diametral pitch $= \dfrac{3{\cdot}1416}{\text{Circular pitch}}$

Circular pitch $= \dfrac{3{\cdot}1416}{\text{Diam. pitch}}$

Pitch Diameter $= \dfrac{\text{No. of teeth}}{\text{Diam. pitch}}$ or $\dfrac{\text{No of teeth} \times \text{cir. pitch}}{3{\cdot}1416}$

Outside diameter $= \dfrac{\text{No. of teeth} + 2}{\text{Diam. pitch}}$ or $\dfrac{(\text{No. of teeth} + 2) \times \text{cir. pitch}}{3{\cdot}1416}$

No. of teeth $=$ pitch diam. × diam. pitch ; or $\dfrac{\text{pitch diam.} \times 3{\cdot}1416}{\text{pitch}}$

Thickness of tooth at pitch line $= \dfrac{\text{circular pitch}}{2}$ or $\dfrac{1{\cdot}57}{\text{diam. pitch}}$

Height of tooth above pitch line, or addendum $= {\cdot}3183$ cir. pitch or $\dfrac{1}{\text{diam. pitch}}$

Working depth of tooth $= {\cdot}6366$ cir. pitch or $\dfrac{2}{\text{diam. pitch}}$

Whole depth of tooth $= {\cdot}6866$ cir. pitch or $\dfrac{2{\cdot}157}{\text{diam. pitch}}$

Clearance at bottom of tooth = one-tenth of thickness of tooth at pitch line.

Distance between the centres of a pair of wheels:

$$= \frac{\text{Sum of number of teeth in both wheels}}{2 \times \text{dia. pitch}}$$

$$\text{or} = \frac{\text{Sum of pitch diameters of both wheels}}{2}$$

Width of face $= \dfrac{8}{\text{diam. pitch}}$ to $\dfrac{10}{\text{diam. pitch}}$ or 2½ to 3½ cir. pitch.

MORSE TAPERS

Number of Tapers.	Smallest Diameter.	Taper per foot.	Length of Shank in Socket.	Smallest Drill using each Taper.	Largest Drill using each Taper.
1	·369	·600	2⅛	⅛	19/32
2	·572	·602	2 9/16	39/64	29/32
3	·778	·602	3 3/16	59/64	1¼
4	1·020	·623	4 1/16	1 17/64	2
5	1·475	·630	5 3/16	2 1/64	3
6	2·116	·626	7¼	Special	

TANGENTS AND COTANGENTS OF ANGLES

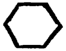
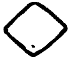
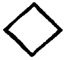
Tangents of Angles.	Cotangents of Angles.	Values.	Tangents of Angles.	Cotangents of Angles.	Values.
°	°		°	°	
78	12	4·70463	84·5	5·5	10·38540
78·5	11·5	4·91516	85	5	11·43005
79	11	5·14455	85·5	4·5	12·70620
79·5	10·5	5·39552	86	4	14·30067
80	10	5·67128	86·5	3·5	16·34985
80·5	9·5	5·97576	87	3	19·08114
81	9	6·31375	87·5	2·5	22·90377
81·5	8·5	6·69116	88	2	28·63625
82	8	7·11537	88·5	1·5	38·18846
82·5	7·5	7·59575	89	1	57·28996
83	7	8·14435	89·5	0·5	114·58865
83·5	6·5	8·77689	90	0	infinite.
84	6	9·51436			

LENGTHS OF CIRCULAR ARCS FROM 1° TO 76° (RADIUS = 1)

Deg.	Length.	Deg.	Length.	Deg	Length	Deg	Length
1	·0175	20	·3491	39	·6807	58	1·0123
2	·0349	21	·3665	40	·6981	59	1·0297
3	·0524	22	·3840	41	·7156	60	1·0472
4	·0698	23	·4014	42	·7330	61	1·0647
5	·0873	24	·4189	43	·7505	62	1·0821
6	·1047	25	·4363	44	·7679	63	1·0996
7	·1222	26	·4538	45	·7854	64	1·1170
8	·1396	27	·4712	46	·8029	65	1·1345
9	·1571	28	·4887	47	·8203	66	1·1519
10	·1745	29	·5061	48	·8378	67	1·1694
11	·1920	30	·5236	49	·8552	68	1·1868
12	·2094	31	·5411	50	·8727	69	1·2043
13	·2269	32	·5585	51	·8901	70	1·2217
14	·2443	33	·5760	52	·9076	71	1·2392
15	·2618	34	·5934	53	·9250	72	1·2566
16	·2793	35	·6109	54	·9425	73	1·2741
17	·2967	36	·6283	55	·9599	74	1·2915
18	·3142	37	·6458	56	·9774	75	1·3090
19	·3316	38	·6632	57	·9948	76	1·3265

Distance across Corners of Squares and Hexagons, given distance across flats

Flats of hexagon × 1·155 equal distance across corners
,, square × 1·414 ,, ,, ,, ,,

Across Flats			
¼	·29	·33	·36
5/16	·36	·41	·44
⅜	·43	·50	·53
7/16	·50	·58	·62
½	·57	·66	·71
9/16	·65	·75	·80
⅝	·72	·83	·88
11/16	·79	·91	·97
¾	·86	1·00	1·06
13/16	·93	1·08	1·15
⅞	1·01	1·16	1·24
15/16	1·08	1·25	1·33
1	1·15	1·33	1·41
1 1/16	1·22	1·42	1·50
1⅛	1·29	1·50	1·59
1 3/16	1·37	1·58	1·68
1¼	1·44	1·66	1·77
1 5/16	1·51	1·75	1·86
1⅜	1·58	1·83	1·94
1 7/16	1·66	1·92	2·03
1½	1·73	2·00	2·12
1 9/16	1·80	2·08	2·21
1⅝	1·88	2·16	2·30
1 11/16	1·95	2·25	2·39
1¾	2·02	2·33	2·47
1 13/16	2·09	2·42	2·56
1⅞	2·17	2·50	2·65
1 15/16	2·24	2·58	2·74
2	2·31	2·66	2·83

CAPACITY OF ROUND TANKS IN LB./INCH.

Diam. in Ins.	Galls. per In.	Petrol.	Refined Paraffin.	Scotch Paraffin.	Crude Oil.	Lubricating Oil.	Fuel Oil.	Water.
		Sp. Gr.	·796	·81	·85	·895	·93	1·0
		·73	(5 per cent. has been deducted.)					
6	·0969	·7074	·7713	·7849	·8236	·8672	·901	·969
7	·1304	·9520	1·038	1·056	1·108	1·167	1·213	1·304
8	·1719	1·255	1·368	1·393	1·461	1·539	1·599	1·719
9	·2180	1·591	1·735	1·766	1·853	1·951	2·027	2·18
10	·2690	1·964	2·149	2·186	2·294	2·416	2·510	2·69
11	·3253	2·375	2·589	2·635	2·765	2·912	3·026	3·253
12	·3876	2·829	3·085	3·14	3·294	3·469	3·605	3·876
14	·5270	3·847	4·195	4·269	4·48	4·717	4·901	5·270
16	·6887	5 027	5·482	5·579	5·854	6·164	6·405	6·887
18	·8722	6·376	6·942	7·064	7·414	7·806	8·112	8·722
20	1 076	7·855	8·566	8·716	9·146	9·632	10·07	10·76
22	1·302	9·504	10·36	10·55	11·07	11·65	12·11	13·02

BROWN AND SHARPE TAPERS.

Used in Spindles of B. and S. Machines.

Taper ½-inch per foot.

Number of Taper.	Diam of Inches at small end.	Number of Taper.	Diam of Inches at small end	Number of Taper.	Diam of Inches at small end.
1	·20	7	·60	13	1·75
2	·25	8	·75	14	2
3	·312	9	·90	15	2·25
4	·35	10	1·05	16	2·50
5	·45	11	1·25	17	2·75
6	·50	12	1·50	18	3

CONVERSION OF MASSES.

	Grains to grams.	Grams to grains.	Ounces (avoir.) to grams.	Grams to ounces (avoir.)	Pounds (avoir.) to kilograms.
1.	0·06480	15·43	28·35	0·03527	0·4536
	Kilograms to pounds.	Short tons (2000 lb.) to metric tons.	Metric tons (1000 k.g.) to short tons.	Long tons (2240 lbs.) to metric tons.	Metric tons to long.
1.	2·205	0·907	1·102	1·016	0·984

GRINDING WHEELS FOR TOOLS AND MACHINE PARTS.

Wheel Classification.	Standard Speed of Surface. Ft. per min.	Maximum Speed of Surface. Ft. per min.
Vitrified and silicate wheels for cylinder grinding	5,500	6,500
Vitrified and silicate wheels for internal grinding	3,500	5,000
Plain wheels, cup and ring wheels and segments for surface grinding	4,000	5,000
Vitrified and silicate plain wheels for fettling and general work	4,500	5,500
Rubber bonded wheels for fettling and general work	7,000	9,000
Rubber, elastic, and Bakelite wheels for cutting off	8,000	10,000
Hemming cylinder for knife grinding, etc. .	2,200	3,300
Vitrified and silicate wheels for edge tool work .	4,500	5,000
Vitrified and silicate wheels for cutlery grinding	5,000	5,500

Work Speeds. For roughing C.I., 40, for finishing, 50 ft./min. surface speed ; for roughing steel 20 to 30, finishing 30 to 40 ft./min.

Grinding Allowances. $\frac{1}{64}$ in. to $\frac{1}{32}$ in. for heavy work, on fine work, 0·003 in. to 0·007 in.

H.P. REQUIRED FOR GRINDING MACHINES.

Type of Grinder.	Wheel Inches.	Motor Recommended.
Plain grinders	12 × 1½	3½–5 H.P.
,, ,, ...	14 × 2	5 –7½ ,,
,, ,, ...	18 × 2	7½–10 ,,
,, ,, ...	18 × 3	12–15 ,,
,, ,, ...	20 × 3	15–20 ,,
,, ,, ...	26 × 3 (18″)	20–25 ,,
,, ,, ...	26 × 3 (24″)	20–25 ,,
,, ,, ...	26 × 3 (30″)	25–30 ,,
,, ,, ...	26 × 3 (36″)	25–30 ,,
Crankshaft grinder	24″ dia.	20–25 ,,
Crankshaft with wheels up to . .	32″ dia.	25–30 ,,

ATOMIC WEIGHTS OF THE COMMONER ELEMENTS (*O* = 16).

Element.	Symbol.	Atomic Weight.	Element.	Symbol.	Atomic Weight.
Aluminium	Al	27·1	Lead	Pb	207·1
Antimony	Sb	120·2	Lithium	Li	6·94
Arsenic	As	74·96	Magnesium	Mg	24·32
Barium	Ba	137·37	Manganese	Mn	54·93
Bismuth	Bi	208·0	Mercury	Hg	200·0
Boron	B	11·0	Nickel	Ni	58·68
Bromine	Br	79·92	Nitrogen	N	14·01
Calcium	Ca	40·09	Oxygen	O	16·00
Cadmium	Cd	112·4	Phosphorus	P	31·04
Carbon	C	12·0	Platinum	Pt	195·2
Chlorine	Cl	35·46	Potassium	K	39·1
Chromium	Cr	52·0	Silicon	Si	28·3
Cobalt	Co	58·97	Silver	Ag	107·88
Copper	Cu	63·57	Sodium	Na	23·0
Fluorine	F	19·0	Strontium	Sr	87·63
Gold	Au	197·2	Sulphur	S	32·07
Hydrogen	H	1·008	Tin	Sn	119·0
Iodine	I	126·92	Tungsten	W	184·0
Iron	Fe	55·85	Zinc	Zn	65·37

TAPERS PER FOOT AND CORRESPONDING ANGLES.

Taper per ft.	Included Angle.		Angle with Centre Line.	
In.	Deg.	Min.	Deg.	Min.
1/8	0	36	0	18
1/4	1	12	0	36
5/16	1	30	0	45
3/8	1	47	0	54
7/16	2	05	1	02
1/2	2	23	1	12
3/4	3	35	1	47
15/16	4	28	2	14
1	4	46	2	23
1 1/2	7	09	3	35
1 3/4	8	20	4	10
2	9	31	4	46
2 1/2	11	54	5	57
3	14	15	7	08
3 1/2	16	36	8	18
4	18	55	9	28

STANDARD TAPER PINS. TAPER 1/4-inch per foot.

No.	Largest Diam. Pin.	Smallest Diam. Pin.
	Inch.	Inch.
0	·156	·135
1	·172	·146
2	·193	·162
3	·219	·183
4	·250	·208
5	·289	·240
6	·341	·279
7	·409	·331
8	·492	·398
9	·591	·482
10	·706	·581

ESTIMATED COST OF RUNNING A.C. MOTORS (Messrs. Brook Motors Ltd.)

Based on the experience that for normal machine driving such as Lathes, Presses and Woodworking Machinery, the actual power to drive the machines at full load should not be taken as the electrical energy consumed over a period.

A load factor has been taken into account in obtaining the following figures which is considered to be reasonably accurate :

	COST PER UNIT IN PENCE														
	¼d.	⅓d.	⅜d.	½d	¾d.	1d.	1¼d	1½d	2d	2½d.	3d.	3½d.	4d.	5d.	6d.
Horse-power	Running Cost per Hour.														
·5	·08	·11	·12	·16	·24	·32	·40	·48	·64	·80	·96	1·1	1·3	1·6	1·9
·75	·10	·13	·15	·20	·30	·40	·50	·60	·80	1·0	1·2	1·4	1·6	2·0	2·4
1	·14	·19	·21	·28	·42	·56	·70	·84	1·1	1·4	1·7	2·0	2·2	2·8	3·4
1·5	·21	·28	·32	·42	·63	·84	1·1	1·3	1·7	2·1	2·5	3·0	3·4	4·2	5·0
2	·25	·33	·38	·50	·75	1·0	1·3	1·5	2·0	2·5	3·0	3·5	4·0	5·0	6·0
2·5	·32	·42	·48	·64	·96	1·3	1·6	1·8	2·6	3·2	3·8	4·5	5·1	6·4	7·7
3	·36	·48	·54	·72	1·1	1·4	1·8	2·2	2·9	3·6	4·3	5·0	5·8	7·2	8·6
4	·44	·58	·66	·88	1·3	1·8	2·2	2·6	3·5	4·4	5·3	6·0	7·0	9·0	11
5	·55	·73	·83	1·1	1·7	2·2	2·8	3·3	4·4	5·5	6·6	7·7	8·8	11	13
6	·66	·87	·99	1·3	2·0	2·6	3·3	4·0	5·2	6·6	7·9	9·2	11	13	16
7½	·81	1·1	1·2	1·6	2·4	3·2	4·1	4·9	6·5	8·1	9·7	11	13	16	20
10	1·1	1·5	1·7	2·2	3·3	4·4	5·5	6·6	8·8	11	13	15	18	22	26
12	1·3	1·7	1·95	2·6	3·9	5·2	6·5	7·8	10	13	15	18	21	26	31
15	1·8	2·4	2·7	3·6	5·4	7·2	9	11	14	18	22	25	29	36	34
20	2·2	2·9	3·3	4·4	6·6	8·8	11	13	18	22	26	31	35	44	53

In the case of Fans, Pumps, etc , where load is constantly applied, increase the above values by 40%.

CONVERSION OF PRESSURES

	Pounds per sq in. to kilograms per sq. cm.	Kilograms per sq. cm. to pounds per. sq. in.	Atmospheres to pounds per sq. in.	Pounds per sq. in. to atmospheres.	Atmospheres to kilograms per sq. cm.	Kilograms per sq. cm. to atmospheres.
1	0·0703	14·22	14·70	0·0680	1·033	0·9678

THE PROPERTIES OF SOME TYPICAL CAST LOW NICKEL BRONZES.

The value of bronze for engineering purposes lies in such factors as its ability to be cast into intricate shapes, its bearing and wearing qualities, corrosion resistance and its mechanical properties. It is only the last of these that can be readily expressed quantitatively, and it is difficult to quote absolute figures for the homogeneity, soundness, flowing powers, shrinkage and the other properties mentioned above, on all of which the presence of nickel in the bronze exerts a favourable influence. A small addition of nickel is particularly valuable in preventing segregation troubles in the leaded bronzes. In alloys free from lead and in the presence of 0.25 per cent. manganese, higher nickel additions make the bronzes susceptible to heat treatment and impart physical properties of a very high order. In this latter connexion a nickel addition of over 4 per cent. is usually required. The following Table indicates the order of mechanical properties obtained in some representative alloys suitable for high duty service.

Ref.	COMPOSITION.						
	Copper.	Tin.	Nickel.	Lead.	Zinc.	Phosphorus.	**Manganese.**
A	88·25	10·5	1·0	—	—	0·25	—
B	81·7	12·0	1·0	5·0	—	0·30	—
C	80·7	10·0	1·0	8·0	—	0·30	—
D	76·7	10·0	1·0	12·0	—	0·30	—
E	88·0	5·0	5·0	—	2·0	—	—
F	88·0	5·0	5·0	—	1·75	—	0·25
G	83·0	7·0	8·0	—	2·0	—	0·25
H	83·0	7·0	8·0	—	2·0	—	0·25

Composition Ref.	MECHANICAL PROPERTIES OF ABOVE COMPOSITIONS.				TYPICAL APPLICATIONS.
	Yield Point tons/sq. in.	Max. Stress tons/sq. in.	Elongation per cent.	Brinell Hardness Number.	
A	8—14	14—22	8—30	70—85	Sand-cast phosphor bronze castings for general purposes.
B	10—14	13—18	4—10	70—80	Heavy duty bearing bronze (i e. for rolling mills).
C	10—12	14—17	6—12	65—75	General purpose bearing bronze for semi-hard shafts.
D	9—12	14—17	8—13	65—75	Bearing bronze for unhardened shafts.
E	10	21	34	75	Sand-cast gunmetal castings. Valve bodies and fittings, etc.
F	23	33	17	136	Sand-cast nickel bronze heated 1400° F. for 10 hrs., water quenched. Reheated 500° F. for 5 hrs., water quenched High duty gunmetal castings.
G	14	22	14	100	Sand-cast gunmetal castings.
H	26	35	1	227	Sand-cast nickel bronze, heated 1400° F. for 2 hrs., water quenched. Reheated 700° F. for 2 hrs., water quenched. Gunmetal castings for resisting wear.

Table 190.—TAPERS PER FOOT WITH CORRESPONDING ANGLES.

Taper per ft.	Included Angle.	Angle with Centre Line.	Taper per ft.	Included Angle.	Angle with Centre Line.
Ins.			Ins.		
$\frac{1}{8}$	0°—36′	0°—18′	1	4°—46′	2°—23′
$\frac{1}{4}$	1°—12′	0°—36′	$1\frac{1}{2}$	7°—09′	3°—35′
$\frac{5}{16}$	1°—30′	0°—45′	$1\frac{3}{4}$	8°—20′	4°—10′
$\frac{3}{8}$	1°—47′	0°—54′	2	9°—31′	4°—46′
$\frac{7}{16}$	2°—05′	1°—02′	$2\frac{1}{2}$	11°—54′	5°—57′
$\frac{1}{2}$	2°—23′	1°—12′	3	14°—15′	7°—08′
$\frac{3}{4}$	3°—35′	1°—47′	$3\frac{1}{2}$	16°—36′	8°—18′
$\frac{15}{16}$	4°—28′	2°—14′	4	18°—55′	9°—28′

SOLDERING

Fluxes used in Soldering

The flux prevents oxidization of the surface of the metal and facilitates the flowing of the solder.

NAME OF METAL.	FLUXES USED.
Brass . . .	Resin, Sal Ammoniac, Chloride of Zinc.
Copper . . .	" " "
Zinc . . .	Hydrochloric Acid dilute.
Iron . . .	Chloride of Zinc, Sal Ammoniac.
Steel . . .	Chloride of Ammonia.
Lead . . .	Tallow, Resin.
Tin . . .	Resin.
Aluminium . .	Stearin.

One millimetre ($\frac{1}{1000}$ part of a metre). = ·03937 inches.
One centimetre . . . . . . = 10 millimetres, or = ·3937 inches.
One decimetre . . . . . . = 10 centimetres, or 3·937 inches.
One metre . . . . = 10 decimetres, or 39·370 inches.
One square millimetre . . . . = ·00155 square inches.
One square centimetre . . . . = ·155 square inches.
One square decimetre . . . . = 15·55 square inches.
One square metre . . . . . = 1550·06 square inches.
One inch . . . . = ·0254 metre.
One foot . . . . = ·3048 metre.
One yard . . . . = ·9143 metre.
One square inch . . . . . = ·000645 square metre.
One square foot . . . . . = ·0928 square metre.
One square yard . . . . . = ·8360 square metre.
One cubic inch . . . . . = 16·387 cubic centimetres.
One cubic foot . . . . . . = 28·3153 cubic decimetres.
One cubic yard . . . . . = ·7645 cubic metre.
Millimetres multiplied by 03937 . . = inches.
Inches multiplied by 25 4. . . = millimetres.

FRENCH WEIGHTS AND MEASURES.

	Troy ounces.	Avoirdupois lb.	Cwt. — 112 lb.
Milligramme	0·000032	0·0000022	0·0000000
Centigramme	0·000322	0·0000220	0·0000002
Décigramme	0·003215	0·0002205	0·0000020
Gramme	0·032151	0·0022046	0·0000197
Décagramme	0·321507	0·0220462	0·0001968
Hectogramme	3·215073	0·2204621	0·0019684
Kilogramme	32·150727	2·2046213	0·0196841
Myrigramme	321·507267	22·0462126	0·1968412

Grain . . . . = 0·064799 gramme.
Troy ounce . . . . = 31·103496 grammes.
Pound avoirdupois . . . . . = 0·453593 kilogrammes.
Cwt. . . . . = 50·802377 kilogrammes.
One centilitre . . . . . . = ·0176 pint.
One decilitre . . . . . . = ·1760 pint.
One litre . . . . = 1·7607 pints.
One litre . . . . = 61·02524 cubic inches.
One litre is a little over 1¾ pints.
Litres multiplied by ·2201 . . . = imperial gallons.
Hectolitre multiplied by 2·7512 . . = bushels.
Grammes multiplied by ·002205 . = pounds avoirdupois
Kilogrammes multiplied by 2·205 . = pounds avoirdupois.
51 kilogrammes . . . . . = nearly 1 cwt.
One metric ton . . . . . . = 1000 kilogrammes.
Tons multiplied by ·984 . . . = French tonnes.

Table 191.—FRENCH MEASURES AND WEIGHTS OF VARIOUS METALS.

	Wrought Iron.	Cast Iron.	Steel.	Copper.	Brass.	Lead.
One circular mètre, one millimètre thick. Weight in kilogrammes	6·04	5·8	6·16	6·96	6·65	8·95
One cubic mètre. Weight in kilogrammes . .	7690·	7280·	7840·	8800·	8420·	1135·
One cylindrical mètre. Weight in kilogrammes .	6040·	5720·	6160·	6910·	6610·	8920·
One square mètre, one millimètre thick. Weight in kilogrammes	7·70	7·30	7·85	8·85	8·45	11·40

The French unit of work is one kilogrammetre, or a pressure of one kilogramme exerted through a space of one metre.

One kilogramme is equal to 7·233 foot pounds.

The French horse-power, or cheval vapeur, is equal to 75 kilogrammetres of work done per second; or equal to 75 × 7·233 = 542·47 foot pounds of work per second.

The French unit of heat is the amount required to raise the temperature of 1 kilogramme of water through 1 C.

The French unit of heat, termed a calorie, is equal to 3·968 British thermal units; and calories × 3·968 = British thermal units.

One British heat-unit is equal to ·252 calorie, and British thermal units × ·252 = calories. The mechanical equivalent of one British heat-unit (Joules' equivalent) is 772 foot-pounds, and equal to 10·67 kilogrammetres. The mechanical equivalent of one French unit of heat is 425 kilogrammetres, or 3,074 foot-pounds. If calculated in terms of Joules' equivalent, the value is 423·55 kilogrammetres, or 3,063·5 foot-pounds.

One calorie per square metre is equal to ·369 heat-units per square foot.

One heat-unit per square foot is equal to 2·713 calories per square metre.

One calorie per kilogramme is equal to 1·800 heat-units per pound.

One heat-unit per pound is equal to ·556 calorie per kilogramme.

One cubic millimetre is = ·000061 cubic feet. One cubic centimetre is = ·061025 cubic inch. One cubic decimetre is = 61·02524 cubic inches, and = ·0353156 cubic feet. One cubic metre is = 35·3156 cubic feet, and = 1·308 cubic yards. One cubic decimetre is = 1,000 cubic metres, and = 1,308 cubic yards. Cubic centimetres ÷ 16·387 = cubic inches. Cubic centimetres ÷ 29·57 = fluid ounces.

Cubic metres × 35·315 = cubic feet. Cubic metres × 1·308 = cubic yards. Cubic metres × 220·1 = gallons = 277·274 cubic inches per gallon. One cubic foot of water = 28·35 kilogrammes.

One pound = 16 ounces, or 7,000 grains = 453·593 grammes, and = 445,000 dynes; and 981,000 dynes = 1 kilogramme. Grammes × 15·4323 = grains. Grammes ÷ 28·35 = ounces avoirdupois. Grammes × 981 = dynes. Hectolitres ÷ 22·009 = gallons. Hectolitres ÷ 2·7511 = bushels.

One kilogramme is = 1,000 grammes = 2·2046 lbs. Kilogrammes × 35·274 = ounces avoirdupois. 1,016 kilogrammes nearly equal one ton. Kilogrammes per square centimetre × 14·2232 = pounds per square inch.

One square metre is = 10·7641 square feet. One kilogramme per square metre is = 1·843 pounds per square yard. One kilogramme per square metre is equal in thickness to ·205 lb. of copper per square foot.

One kilogramme-degree C. is = 4,200 joules. One British thermal-unit is = 1,058 joules. Watts = volts × ampères = joules per second. One watt-second is = 1 joule. One watt-hour is = 3,600 joules. One watt is equal to about 44¼ foot-pounds. One kilo-watt is = 1·34 horse-power. One electrical horse-power is = 746 watts. Electrical energy is sold in units of 1,000 watt-hours each, termed Board of Trade units. One Board of Trade unit is = 1,000 watt-hours ÷ 746 watts = 1⅓ horse-power per hour.

One foot-pound is = ·138 kilogrammetre. One pound per horse-power is = ·447 kilogrammes per cheval vapeur. One kilogrammetre is = 7·233 foot-pounds. One horse-power is = 1·0139 cheval vapeur, and cheval vapeur × ·9863 = horse-power. One kilogramme per cheval is = 2·235 pounds per horse-power. One square metre per cheval is = 10·913 square feet per horse-power. One cubic metre per cheval is equal to 35·806 cubic feet per horse-power.

Table 192.—MILLIMETRE-EQUIVALENTS OF PARTS OF AN INCH AND PARTS OF A FOOT.

Sixty-fourths of an Inch.	Millimetres.	Thirty-seconds of an Inch.	Millimetres.	Sixteenths of an Inch.	Millimetres.	Inches.	Millimetres.
1	·397	1	·794	1	1·587	$\frac{1}{64}$	·397
3	1·191	3	2·381	3	4·762	$\frac{1}{32}$	·794
5	1·984	5	3·969	5	7·937	$\frac{1}{16}$	1·587
7	2·778	7	5·556	7	11·112	$\frac{1}{8}$	3·175
9	3·572	9	7·144	9	14·287	$\frac{1}{4}$	6·350
11	4·366	11	8·731	11	17·462	$\frac{3}{8}$	9·525
13	5·159	13	10·319	13	20·637	$\frac{1}{2}$	12·700
15	5·953	15	11·906	15	23·812	$\frac{5}{8}$	15·875
17	6·747	17	13·493			$\frac{3}{4}$	19·050
19	7·540	19	15·081			$\frac{7}{8}$	22·225
21	8·334	21	16·668			1	25·400
23	9·128	23	18·256			2	50·799
25	9·922	25	19·843			3	76·199
27	10·715	27	21·431			4	101·598
29	11·509	29	23·018			5	126·998
31	12·303	31	24·606			6	152·397
33	13·097					7	177·797
35	13·890					8	203·196
37	14·684					9	228·596
39	15·478					10	253·995
41	16·272					11	279·395
43	17·065					12	304·794

Table 193.—FRACTIONAL PARTS OF AN INCH AND THEIR DECIMAL EQUIVALENTS.

Inch.	Inch.	Inch.	Inch.
$\frac{1}{32}$	·03125	$\frac{1}{2}$ and $\frac{1}{32}$	·53125
$\frac{1}{16}$	·0625	$\frac{9}{16}$	·5625
$\frac{3}{32}$	·09375	$\frac{9}{16}$ and $\frac{1}{32}$	·59375
$\frac{1}{8}$	·125	$\frac{5}{8}$	·625
$\frac{5}{32}$	·15625	$\frac{5}{8}$ and $\frac{1}{32}$	·65625
$\frac{3}{16}$	·1875	$\frac{11}{16}$	·6875
$\frac{7}{32}$	·21875	$\frac{11}{16}$ and $\frac{1}{32}$	·71875
$\frac{1}{4}$	·25	$\frac{3}{4}$	·75
$\frac{1}{4}$ and $\frac{1}{32}$	·28125	$\frac{3}{4}$ and $\frac{1}{32}$	·78125
$\frac{5}{16}$	·3125	$\frac{13}{16}$	·8125
$\frac{5}{16}$ and $\frac{1}{32}$	·34375	$\frac{13}{16}$ and $\frac{1}{32}$	·84375
$\frac{3}{8}$	·375	$\frac{7}{8}$	·875
$\frac{3}{8}$ and $\frac{1}{32}$	·40625	$\frac{7}{8}$ and $\frac{1}{32}$	·90625
$\frac{7}{16}$	·4375	$\frac{15}{16}$	·9375
$\frac{7}{16}$ and $\frac{1}{32}$	·46875	$\frac{15}{16}$ and $\frac{1}{32}$	·96875
$\frac{1}{2}$	·5	1	1·0

Table 194.—FRACTIONAL PARTS OF 1 FOOT AND THEIR DECIMAL EQUIVALENTS.

Inch.	Foot.	Inch.	Foot.	Inch.	Foot.	Inch.	Foot.
⅛	·01041	¾	·0625	4	·3333	9	·75
¼	·02083	⅞	·07291	5	·4166	10	·8333
⅜	·03125	1	·0833	6	·5	11	·9166
½	·04166	2	·1666	7	·5833	12	1·0000
⅝	·05208	3	·25	8	·6666		

Table 195.—SQUARE INCHES INTO DECIMAL PARTS OF 1 FOOT SQUARE.

Inches.	Foot.	Inches.	Foot.	Inches.	Foot.	Inches.	Foot.
144	1·00	72	·50	13	·09	7	·05
130	·90	57	·40	11	·08	6	·04
115	·80	43	·30	10	·07	4·3	·03
100	·70	28	·20	9	·06	2·9	·02
87	·60	14	·10	8	·056	1·4	·01

Table 196.—SURFACE OF TUBES, 1 FOOT LONG, IN DECIMAL PARTS OF A SQUARE FOOT.

Bore.	Surface.	Bore.	Surface.	Bore.	Surface.	Bore.	Surface.
⅝	·1636	1⅛	·2945	1⅝	·4253	2¼	·5894
¾	·1963	1¼	·3270	1¾	·4580	2½	·6540
⅞	·2291	1⅜	·3599	1⅞	·4906	2¾	·7194
1	·2618	1½	·3927	2	·5233	3	·7859

Table 197.—EQUIVALENT RATES PER LB. AND PER CWT.

Rate per lb.	Rate per cwt.			Rate per lb.	Rate per cwt.			Rate per lb.	Rate per cwt.		
Pence.	£	s.	d.	Pence.	£	s.	d.	Pence.	£	s.	d.
¼	0	2	4	2¾	1	5	8	7½	3	10	0
½	0	4	8	3	1	8	0	8	3	14	8
¾	0	7	0	3½	1	12	8	8½	3	19	4
1	0	9	4	4	1	17	4	9	4	4	0
1¼	0	11	8	4½	2	2	0	9½	4	8	8
1½	0	14	0	5	2	6	8	10	4	13	4
1¾	0	16	4	5½	2	11	4	10½	4	18	0
2	0	18	8	6	2	16	0	11	5	2	8
2¼	1	1	0	6½	3	0	8	11½	5	7	4
2½	1	3	4	7	3	5	4	12	5	12	0

Table 198.—New Imperial Standard Wire Gauge.

Descriptive Number.	Equivalents in parts of an Inch.	Descriptive Number.	Equivalents in parts of an Inch.	Descriptive Number.	Equivalents in parts of an Inch.	Descriptive Number.	Equivalents in parts of an Inch.
7/0	·500	9	·144	23	·024	37	·0068
6/0	·464	10	·128	24	·022	38	·0060
5/0	·432	11	·116	25	·020	39	·0052
4/0	·400	12	·104	26	·018	40	·0048
3/0	·372	13	·092	27	·0164	41	·0044
2/0	·348	14	·080	28	·0148	42	·0040
0	·324	15	·072	29	·0136	43	·0036
1	·300	16	·064	30	·0124	44	·0032
2	·276	17	·056	31	·0116	45	·0028
3	·252	18	·048	32	·0108	46	·0024
4	·232	19	·040	33	·0100	47	·0020
5	·212	20	·036	34	·0092	48	·0016
6	·192	21	·032	35	·0084	49	·0012
7	·176	22	·028	36	·0076	50	·0010
8	·160						

Table 199.—Fractional Parts of a Pound Avoirdupois and their Decimal Equivalents.

Ounces.	Lbs.	Ounces.	Lbs.	Ounces.	Lbs.
¼	·015625	5½	·34375	11	·6875
½	·03125	6	·375	11½	·71875
1	·0625	6½	·40625	12	·75
1½	·09375	7	·4375	12½	·78125
2	·125	7½	·46875	13	·8125
2½	·15625	8	·5	13½	·84375
3	·1875	8½	·53125	14	·875
3½	·21875	9	·5625	14½	·90625
4	·25	9½	·59375	15	·9375
4½	·28125	10	·625	15½	·96875
5	·3125	10½	·65625	16	1·000

Millimetre Equivalents of the Imperial Standard Wire Gauge are given at page 313, but the following are useful approximate equivalents.

Table 200.—Approximate Millimetre-Equivalents of the Imperial Standard Wire Gauge.

Imperial Standard Wire Gauge	24	23	22	21	20	19	18
Millimetres . . .	·55	·60	·70	·80	·90	1	1¼
Imperial Standard Wire Gauge	16	15	14	13	12	11	10
Millimetres . . .	1½	1¾	2	2¼	2½	3	3¼

Table 201.—Fractional Parts of a Hundredweight and their Decimal Equivalents.

Lbs.	Cwt.	Qrs. Lbs.	Cwt.	Qrs. Lbs.	Cwt.	Qrs. Lbs.	Cwt.
½	·0044	1 0	·25	2 0	·5	3 0	·75
1	·0089	1 1	·2590	2 1	·5089	3 1	·7589
2	·0178	1 2	·2678	2 2	·5178	3 2	·7678
3	·0268	1 3	·2768	2 3	·5268	3 3	·7768
4	·0357	1 4	·2857	2 4	·5357	3 4	·7857
5	·0446	1 5	·2946	2 5	·5446	3 5	·7946
6	·0535	1 6	·3035	2 6	·5535	3 6	·8035
7	·0625	1 7	·3125	2 7	·5625	3 7	·8125
8	·0714	1 8	·3214	2 8	·5714	3 8	·8214
9	·0803	1 9	·3303	2 9	·5803	3 9	·8303
10	·0892	1 10	·3392	2 10	·5892	3 10	·8392
11	·0982	1 11	·3482	2 11	·5982	3 11	·8482
12	·1071	1 12	·3571	2 12	·6077	3 12	·8571
13	·1160	1 13	·3660	2 13	·6160	3 13	·8660
14	·1250	1 14	·375	2 14	·6250	3 14	·8750
15	·1339	1 15	·3839	2 15	·6339	3 15	·8839
16	·1429	1 16	·3930	2 16	·6429	3 16	·8929
17	·1518	1 17	·4018	2 17	·6518	3 17	·9018
18	·1607	1 18	·4107	2 18	·6607	3 18	·9107
19	·1696	1 19	·4196	2 19	·6696	3 19	·9196
20	·1786	1 20	·4286	2 20	·6786	3 20	·9286
21	·1876	1 21	·4375	2 21	·6875	3 21	·9375
22	·1964	1 22	·4464	2 22	·6964	3 22	·9464
23	·2054	1 23	·4554	2 23	·7054	3 23	·9554
24	2143	1 24	·4643	2 24	·7143	3 24	·9643
25	·2232	1 25	·4732	2 25	·7232	3 25	·9732
26	·2321	1 26	·4821	2 26	·7321	3 26	·9821
27	·2411	1 27	·4911	2 27	·7411	3 27	·9911

DECIMAL APPROXIMATES, ETC.

Area of a circle = diameter ^{2} × ·7854.

Area of a circle × ·6366 = area of inscribed square.

Area of an ellipse = the product of the two axes × ·7854.

Circumference of a circle = diameter × 3·1416.

The circumference of a circle is nearly equal to 22 times the diameter divided by 7.

Circumference of a circle × ·2821 = side of a square of equal area.

Diameter of a circle = circumference ÷ 3·1416.

Diameter of a circle = square root of the quotient of the area divided by ·7854.

The diameter of a circle is nearly equal to 7 times the circumference divided by 22. The difference of the diameters of any two circles, multiplied by 3·1416, will give the difference of their circumference.

Cubic inches × ·028848 = pints.
Cubic inches × ·014424 = quarts.
Cubic inches × ·003606 = gallons.
Cubic inches × ·0163 = French litres.
Cubic inches in imperial gallon = 277·274.
Cubic feet × 6·232 = imperial gallons.
Cubic feet × ·779 = bushels.
Diameter of circle × ·8862 = side of equal square.
Diameter of circle × ·7071 = side of inscribed square.
Surface of a sphere = diameter ^{2} × 3·1416.
Solidity of a sphere = diameter ^{3} × ·5236.
Diameter of a sphere × ·806 = dimensions of equal cube.
Diameter of a sphere × ·6667 =length of equal cylinder.
Side of a square × 1·1284 = diameter of a circle of equal area.
Side of a square multiplied by 3·545 = circumference of a circle of equal area.
Side of an inscribed square × 1·4142 = diameter of the circumscribing circle.
Side of an inscribed square × 4·4430 = circumference of the circumscribing circle.
Circular inches multiplied by ·7854 = square inches.
Square inches divided by ·7854 = circular inches.
Circular inches multiplied by ·00456 = square feet.
Square inches multiplied by ·00695 = square feet.
Square feet multiplied by ·111 = square yards.
Cubic inches multiplied by ·00058 = cubic feet.
Cubic feet multiplied by ·03704 = cubic yards.
Cylindrical feet multiplied by ·02909 = cubic yards
Links multiplied by ·66 = feet.
Feet multiplied by 1·5 = links.
Square links multiplied by ·4356 = square feet.
Square feet multiplied by 2·3 = square links.
Knots multiplied by 1·15 = miles.
Miles multiplied by ·87 = knots.
Statute acres multiplied by 4840 = square yards.
Grains multiplied by ·0001429 = lbs. avoirdupois.
Pounds avoirdupois multiplied by 7000 = grains.
Area of a parabola = base × height × ⅔.
Area of a triangle = ½ base × perpendicular height.
Area of sector of a circle = length of arc × ½ radius.
Area of a trapezium = ½ sum of the two parallel sides × height.
Area of a rhombus or rhomboid = base × height.
Area of egg-shaped sewer = one-half the square of the depth.

Table 202.—PROPERTIES OF AIR, FROM OBSERVATIONS AT GREENWICH OBSERVATORY.—BAROMETER 30 INCHES AT 60° FAHRENHEIT.

Temperature of the Air.	Force of Vapour in Inches of Mercury.	Weight of Vapour per cubic foot of saturated Air.	Weight per cubic foot.		Temperature of the Air.	Force of Vapour in Inches of Mercury.	Weight of Vapour per cubic foot of saturated Air.	Weight per cubic foot.	
			Dry Air	Saturated Air				Dry Air	Saturated Air
° Fahr.	Inches.	Grains.	Grains.	Grains	° Fahr.	Inches.	Grains.	Grains.	Grains.
10	·089	1·11	590·0	589·4	52	·400	4·56	540·5	537·9
12	·096	1·19	587·5	586·8	54	·428	4·86	538·3	535·5
14	·104	1·28	584·9	584·2	56	·458	5·18	536·2	533·2
16	·112	1·37	582·4	581·6	58	·489	5·51	534·1	530·9
18	·120	1·47	579·9	579·1	60	·523	5·87	532·0	528·6
20	·129	1·58	577·4	576·5	62	·559	6·25	529·9	526·3
22	·139	1·69	575·0	574·0	64	·597	6·65	527·8	524·0
24	·150	1·81	572·5	571·5	66	·638	7·08	525·8	521·7
26	·161	1·93	570·1	569·0	68	·681	7·53	523·7	519·4
28	·173	2·07	567·7	566·5	70	·727	8·00	521·7	517·2
30	·186	2·21	565·3	564·1	72	·776	8·50	519·7	514·9
32	·199	2·37	563·0	561·6	74	·827	9·04	517·7	512·6
34	·214	2·53	560·7	559·2	76	·882	9·60	515·7	510·3
36	·230	2·71	558·3	556·8	78	·940	10·19	513·8	508·0
38	·246	2·89	556·0	554·4	80	1·001	10·81	511·8	505·7
40	·264	3·09	553·8	552·0	82	1·067	11·47	509·9	503·4
42	·283	3·30	551·5	549·6	84	1·136	12·17	508·0	501·1
44	·304	3·52	549·3	547·2	86	1·209	12·91	506·1	498·9
46	·326	3·76	547·0	544·9	88	1·286	13·68	504·2	496·6
48	·319	4·01	544·8	542·5	90	1·368	14·50	502·3	494·3
50	·373	4·28	542·6	540·2	92	1·456	15·33	500·4	492·0

Table 203. MEAN TEMPERATURE OF THE AIR AT VARIOUS PLACES.

Name of place.	Mean Temp.		Height above the Sea. Feet.	Name of Place.	Mean Temp.		Height above the Sea. Feet.
	Summer	Winter			Summer	Winter	
	° Fahr.	° Fahr.			° Fahr.	° Fahr.	
Algiers	75	54	310	Madrid	74	42	2175
Berlin	63	31	128	Mexico, City	64	60	6993
Berne	61	31	1918	Montreal	69	18	—
Boston, America	66	28	71	Moscow	63	14	480
Buenos Ayres	73	53	—	Naples	75	50	180
Cairo	85	59	—	New Orleans	84	57	22
Calcutta	84	68	—	New York	72	33	21
Canton	82	55	11	New Zealand	67	54	—
Cape of Good Hope	75	59	—	Nice	73	49	—
Ceylon, Candy	73	72	1684	Paramatta, Australia	74	55	—
Christiania	60	26	74	Paris	65	38	210
Constantinople	74	41	150	Pekin, China	78	29	97
Copenhagen	63	32	20	Philadelphia	75	34	30
Dresden	63	32	397	Quito, Ecuador	61	60	9560
Edinburgh	58	39	288	Rio Janeiro	79	69	11
Hobart Town	63	42	—	Rome	74	47	174
Jamaica	82	77	10	San Francisco	59	53	150
Jerusalem	73	50	2500	Stockholm	61	26	134
Lima, Peru	74	60	511	St. Petersburg	61	17	10
Lisbon	72	53	236	St. Bernard Alps	43	18	8180
London	62	40	50	Siberia, Irkutsk	63	−38	—
Madeira, Funchal	70	62	—	Vienna	69	34	500

Table 204.—MEAN ANNUAL RAINFALL IN INCHES AT VARIOUS PLACES.

	Inches.		Inches.
Algiers	37·00	Lancashire, Marple	36·56
Baltimore	42·00	Lancashire, Bury	41·70
Bengal, on Khasia Hills	600·00	Lancashire, Coombs	45·80
Bergen, Norway	87·60	Lancashire, Rochdale	46·75
Berlin, Prussia	23·56	Lancashire, Bolton	49·50
Berks, Reading	25·40	Lancashire, Crawshawbooth	60·00
Berks, Hungerford	26·58	Lille, France	29·00
Bombay, India	110·00	Lima, Peru	13·50
Bordeaux	25·80	Lincolnshire, Lincoln	20·20
Boston, North America	44·50	Lincolnshire, Boston	23·10
Bucks, Aylesbury	28·40	London	24·00
Buffalo, North America	27·36	Madeira Islands	30·87
Calcutta, India	73·00	Middlesex, Chiswick	24·00
Canton, China	69·30	Middlesex, Tottenham	24·80
Charleston, North America	48·30	Milan, Italy	38·00
Cheshire, Todd's Brook R'voir	38·40	Mississippi State	53·00
Cheshire, Coomb's Reservoir	51·30	New Orleans	52·32
Copenhagen	18·36	New York	42·24
Cornwall, Penzance	41·10	Norfolk, Felthorp	22·60
Cornwall, Pencarran	45·30	Norfolk, Dickleborough	25·00
Cumberland, Stye-in-Borrowdale	165·00	Northampton, Wellingborough	24·90
Cumberland, Keswick	67·50	Ohio State	22·65
Cumberland, Whitehaven	47·00	Paris	22·65
Cumberland, Cockermouth	45·40	Pekin	26·92
Derbyshire, Chatsworth	27·80	Pentland Hills	36·12
Derbyshire, Chapel-en-le-Frith	43·00	Peru, Carabaya	355·00
Devonshire, Exeter	29·20	Philadelphia	48·20
Devonshire, Honiton	33·20	Pisa	49·00
Devonshire, Plymouth	35·70	Rivington Pike	56·50
Devonshire, Goodamoor	56·80	Rome, Italy	30·80
Dover, Kent	37·50	San Francisco	83·10
Dublin	25·00	Somersetshire, Bridgewater	29·30
Edinburgh	27·00	Somersetshire, Bath	32·40
England, average for whole of	36·00	St. Petersburg, Russia	17·64
Essex	21·00	Stockholm	19·68
Genoa, Italy	56·00	Surrey, Cobham	24·42
Glasgow	28·00	Sussex, Hastings	32·00
Granada, Colombia	115·00	Swineshaw Brook, near Staley Bridge	49·30
Greenock	60·00	Tiflis	19·25
Hampshire, Fyfield	25·90	Venice	31·12
Hampshire Gosport	30·20	Viviers	34·10
Hampshire, Southampton	30·30	Washington	41·25
Hampshire, Selborne	37·20	Westmorland, Waith Sutton	40·62
Havannah	91·20	Westmorland, Kendal	58·12
Island of Cuba	141·00	Westmorland, Grasmere	107·51
Island of San Domingo	120·00	Westmorland, Gatesgarth	117·20
Lancashire, Moss Lock, near Rochdale	30·30	Westmorland, Seathwaite	140·60
Lancashire, Liverpool	34·70	Yorkshire, York	22·30
Lancashire, Blackstone-edge	36·30	Yorkshire, Sowerby Bridge	27·00
Lancashire, Manchester	37·30	Yorkshire, Barrowsby	27·51

An inch of rainfall on a square yard of surface represents a fall of 46·74 lbs., or 4·67 gallons: on an acre it represents a fall of 22,622 gallons, equal to about one hundred tons per inch in depth per acre.

Inches of rainfall × 14·501 = millions of gallons per square mile: ditto × 2,323,200 = cubic feet per square mile: ditto × 3630 = cubic feet per acre.

Motor-Cars.—The calorific power of the petroleum spirit, or petrol, consumed in petrol-engines is 19803 thermal units. The consumption of petrol by the engines of motor-cars is frequently one gallon during a run of 25 miles. The results of petrol consumption competitions are generally worked out on this formula:—

$$\frac{\text{Weight in lbs. of motor-car, and passengers}}{\text{Weight in ounces of petrol consumed on the trial}}$$

The power of petrol-engines of motor-cars up to 25 brake-horse-power, at a normal speed of 1000 revolutions per minute, may be estimated by this rule:—

Brake-horse-power of petrol-motor $= (D^2 \times N \times \sqrt[2]{S}) \div 7$.

In which D = Diameter of one cylinder in inches; N = Number of cylinders; S = Length of stroke in inches.

The power of petrol-engines of all sizes may be estimated by this rule:—

Brake-horse-power of petrol-motor $= [(A \times S) \div C] \times N$.

In which A = Area in square inches of one cylinder; S = Length of stroke in inches; N = Number of cylinders; C = A speed constant = 15·71 for 700 revolutions per minute; 13·75 for 800; 12·22 for 900; 11 for 1000; 10 for 1100; 9·16 for 1200; 8·46 for 1300; 7·85 for 1400; 7.33 for 1500; 6·81 for 1600; 6·47 for 1700; 6·11 for 1800; 5·79 for 1900; and 5·5 for 2000.

Hill-climbing contests by motor-cars are sometimes decided on this formula:—

$$\text{Merit} = \frac{\text{Time in seconds} \times \text{horse-power of motor}}{\text{Total weight in lbs. of motor-car and passengers}}$$

The horse-power in which is, in some cases, found by multiplying the square of the diameter of one cylinder in inches by the number of cylinders, and dividing the product by 3. In other cases the horse-power is decided by this rule:—

$$\text{H. P.} = \frac{\left(\begin{array}{c}\text{Diameter of one cylinder}\\ \text{in inches}\end{array}\right)^2 \times \left(\begin{array}{c}\text{Length of stroke}\\ \text{in inches}\end{array}\right) \times \left(\begin{array}{c}\text{Number of}\\ \text{cylinders}\end{array}\right)}{10}$$

Another hill-climbing formula is:—

$$\text{Merit} = \frac{\text{Horse-power} \times 100000}{\text{Price in £} \times 8 \text{ for every shillingsworth of petrol consumed}}$$

The horse-power in this formula is calculated by this rule:—

$$\text{H.P.} = \frac{\dfrac{\left(\begin{array}{c}\text{Vertical height of hill}\\ \text{in feet}\end{array}\right) \times \left(\begin{array}{c}\text{Weight of motor-car and load in lbs.}\\ +40 \text{ lbs. for every ton of total weight}\end{array}\right)}{\text{Time in minutes}}}{33000}$$

Another hill-climbing formula is:—

$$\text{Merit} = \frac{\text{Time in seconds} \times \text{cylinder capacity in cubic inches}}{\text{Total weight of the motor-car and passengers in lbs.}}$$

Cylinder-dimensions are sometimes in millimetres, which, divided by 25·4 = inches.

Tractive Resistance of Motor-Cars and other Vehicles on Roads.—The resistances opposed to the traction of vehicles on roads are axle-friction, rolling resistance, and gradient resistance. The tractive effort necessary to overcome axle friction is generally from 2½ to 5 lbs. per ton of the weight on the axles.

Rolling resistance depends upon the smoothness, firmness, and construction of the road, and also upon the depth the wheels sink into the road, as they are then continually climbing inclinations.

Gradient resistance is generally equal to 23 lbs. per ton for one per cent. of inclination.

Wheels with tyres of a yielding nature like india-rubber, and consequently pneumatic tyres not fully inflated, offer greater resistance to traction than iron tyres.

Table 205.—Tractive Resistance of Motor Cars and other Vehicles with Wheels having different kinds of Tyres, on Roads of various Descriptions.

Description of Road.	Wheels with iron tyres.	Wheels with solid india-rubber tyres.	Wheels with pneumatic tyres 3½ ins. broad.	Wheels with pneumatic tyres 5 ins. broad.	Wheels with pneumatic tyres 5 ins. broad, with a non skidding band of leather with studs.
	Tractive-Resistance in lbs. per ton of the Weight of the Vehicle.				
Asphalte road, dry	25	30	35	40	50
Road of wood blocks, dry ...	35	40	45	50	60
Road of stone setts, dry ...	40	45	50	55	70
Macadamised main road, dry...	45	55	60	70	80
Gravel road, dry	60	70	80	90	100
Road covered with thick mud...	70	80	90	100	110
Soft macadamised road ...	100	110	120	130	140
Clay road, dry...	110	120	130	140	150
Road of rough stones, dry ...	200	220	230	240	250
Grass fields, dry	230	250	260	270	280
Sand road, dry...	360	380	390	400	410
Road of loose sand, dry ...	560	580	590	600	610

Motor-Boats.—The Marine Association's rule for the power of petrol-engines is:—$(A \times S \times R) \div C$, in which $A =$ the total piston-area in square inches; $S =$ the length of stroke in inches; $R =$ the maximum number of revolutions per minute; $C = 1000$ for 4-cycle, and 600 for 2-cycle motors. These constants are based on the assumption that for a 4-cycle motor the effective mean pressure in the cylinder is 66 lbs. per square inch, and 55 lbs. per square inch in the 2-cycle motor, under ordinary racing conditions.

PATENTS.

Application for and Grants of Patents.—Grants of patents are made through the Patent Office subject to the provisions enacted by Parliament (*a*).

Under the Patents and Designs Act, 1907 (7 Edw. VII, c. 29), any person, whether a British subject or not, may apply for a patent. Two or more persons may make a joint application for a patent, and a patent may be granted to them jointly. The application, which must be in a prescribed form, must be sent to the Patent Office (*b*), and must contain a declaration that the applicant is in possession of an invention of which he (or one of the applicants, if more than one) claims to be the first inventor, and be accompanied by either a provisional or complete specification (*c*).

A *provisional specification* must describe the nature of the invention. A *complete specification* must particularly describe and ascertain the nature of the invention and the manner in which the same is to be performed (§ 2).

If the applicant does not leave a complete specification with his application, he may leave it at any subsequent time within twelve (*d*) months (which may be extended by one month) from the date of the application. If not left within that time the application shall be deemed to be abandoned (§ 5) (*e*).

If the examiner reports that the invention is not particularly described and ascertained in the complete specification or that the invention described in the complete specification is not the same as that described in the provisional specification, the Comptroller may refuse to accept the complete specification, unless amended to his satisfaction, or, with the applicant's consent, cancel the provisional specification and treat the application as having been made when the complete specification was left. Appeal lies from the Comptroller's decision to the Appeal Tribunal (§ 6 as amended by the Patents and Designs Act, 1932 (schedule)).

Procedure after Application.—(i) Where application for a patent has been made and a complete specification deposited, the Patent Office examiner is required (in addition to other formal inquiries directed by the Act) to make a further investigation for the purpose of ascertaining whether the invention claimed has been wholly or in part claimed or described in any previous specification (other than a provisional specification not followed by a complete specification) published before the date which the patent applied for would bear if granted and left pursuant to any application for a patent made in the United Kingdom within fifty years next before such date. (ii) If on investigation it appears that the invention has been wholly or in part claimed or described in any such specification, the applicant may amend his specification, and the amended specification shall be investigated in like manner. (iii) If after the

---

(*a*) The Patent Office is located at 25 Southampton Buildings, Chancery Lane, London.

(*b*) It may be sent by post.

(*c*) The specification may be amended and if the Comptroller refuses to allow the amendment, appeal lies to the law officer (see § 21).

(*d*) The word twelve was substituted for nine by the Patents and Designs Act, 1932 (Schedule).

(*e*) Amended by 9 & 10 Geo. V. c. 80 (§ 20).

examiner's report the Comptroller is satisfied that no objection exists to the specification on the ground that the invention claimed thereby has been wholly or in part claimed or described in a previous specification, he shall, in the absence of any other lawful ground of objection, accept the specification. (iv) If he is not so satisfied, he shall, unless the objection be removed to his satisfaction, determine whether a reference to any prior specifications ought to be made in the specification by way of notice to the public (*a*). (v) If it is within the Comptroller's knowledge that the invention claimed has been published within the United Kingdom before the date which the patent applied for would bear if granted in any document (other than a United Kingdom specification or a specification describing the invention for the purpose of an application for protection made in any country outside the United Kingdom more than fifty years next before that date or any abridgment of or extract from, any such specification published under the authority of the Comptroller or of the government of any country outside the United Kingdom) the provisions of (ii), (iii), and (iv) of this section apply in relation to a claim. Appeal lies to the Appeal Tribunal against the Comptroller's decision (§ 7 Amended by the Patents and Designs Acts, 1919, 1928, and 1932).

On the acceptance of the complete specification the Comptroller shall advertise the acceptance; and the application and specification, with the drawings, samples and specimens (*b*) shall be open to public inspection (§ 9).

(*a*) If satisfied that the invention has been wholly and specifically claimed or described in any specification the Comptroller in lieu of requiring references may refuse to grant a patent.

(*b*) See Patents and Designs Act, 1932 (Schedule).

REMEDIES FOR WORKSHOP ACCIDENTS, ETC.

In cases of accident, the following instructions should be observed, pending the arrival of medical aid:—

Apoplexy.—Raise the head and body, bare the head and neck, and promote circulation of fresh air.

Bleeding.—If the blood spurts from a wound, an artery is divided; bind the limb tightly *above* the wound with a handkerchief, scarf, or strap. If the blood does not spurt, but flows freely, a vein is divided; bind the limb tightly *below* the wound. Raise the injured limb above the level of the body, and press the place from which the blood flows with the thumb, until a pad and bandage can be got ready, with which stop up the wound. If the scalp is wounded, apply a pad of cloth, and bandage it tightly over the wound with a pocket handkerchief.

Broken Arm.—Pull the arm to the same length as the sound one; apply a wood splint to each side of the arm, and bind them firmly above and below the fracture, with bandages or pocket handkerchiefs.

Broken Collar Bone.—Bend the arm over the front of the chest, place it in a sling, and bind it in that position by a scarf, going round the chest, outside the sling.

Broken Jaw.—Bind a handkerchief under the chin and over the top of the head, and bind another across the chin and round the nape of the neck.

Broken Leg.—Pull the leg to the same length as the sound one, roll up a sack or rug into the form of a cushion, and place the leg carefully upon it, and with handkerchiefs or scarves bind the two together. Do not move the sufferer until the stretcher arrives, and use care in lifting to prevent the broken bone coming through the skin.

Broken Ribs.—Cause great pain when breathing; bind a long broad bandage firmly round the chest.

Broken Thigh.—Pull the leg to the same length as the sound one; the knees must next be tied together, and afterwards tie the ankles together; then lay both limbs over a sack of straw or folded rug, so as to bend the knees. The sufferer not to be moved until the stretcher arrives.

Bruises.—Apply iced water, or ice.

Burns.—For slight burns, apply soft soap, or immerse the part in cold water until the pain subsides. Afterwards cover the part with flour and linseed oil, to exclude the air. For severe burns, apply cotton wool soaked in treacle and water, or in linseed oil, or oil and lime-water, and bind the same on with a handkerchief; or apply whiting mixed with oil or water to the consistency of thick cream. For burns by vitriol or sulphuric acid apply dry whiting; for carbolic acid apply water, and oil afterwards.

Choking.—Go down on hands and knees and cough.

Cracked Skin on Fingers.—Apply warm shoemakers' wax.

Cuts.—Perchloride of iron quickly arrests bleeding in cuts and slight wounds, and it should be kept in every factory. Remove dirt from and close the wound; then apply a pad soaked in either perchloride of iron, or in Friar's balsam, and bind round with linen.

Dog Bites.—For bites of mad dogs and other animals, apply a ligature, or cord, on the side nearest the heart, suck the wound, scratch the edges with a penknife, and apply caustic or carbolic acid to the wound.

Drowning.—Dr. Sylvester's Method.—Take the wet clothes off the upper part of the body; lay the sufferer on his back, with his head on a folded rug for a cushion. Having cleared the mouth of any dirt, draw the tongue out of the mouth and hold it there. This opens the wind pipe. A second person kneels at the sufferer's head, and takes hold of both his arms, just below the elbows. He then draws them upwards over the sufferer's head, and holds them in that position until he counts two. This draws air into the lungs. He then lowers the arms to the sides again, and presses them firmly inwards, holding them there until he has again counted two. This forces the air out of the lungs. Continue this process until he breathes naturally, when the limbs should be rubbed in an upward direction with dry hands or with hot flannel. Finally put the sufferer to bed between blankets surrounded with hot water bottles.

Dr. Taylor's Method.—It is stated that some doctors do not consider the Sylvester method of artificial respiration suitable in cases of drowning, among whom is Doctor C. B. Taylor, who recommends the following treatment:—Place the knees of the patient over someone's shoulders and so incline the body that the water will run out, a process which will be greatly facilitated (and this is very important) by pulling forward the tongue; wet clothes should be stripped off, dry ones substituted, and the limbs rubbed and manipulated so as to restore the circulation if possible. After emptying the chest, place the body on one side with the head slightly dependent, and keep pulling the tongue forward. If there be breathing wait and watch. If there be no breathing or efforts at respiration, place the patient at once on his face with a small hardish bundle (his bent arm will do) under his forehead, and another under his chest, then make firm pressure on the back so as to expel any residual air, and turn the body slowly over on to one side and a little beyond; replace the body quickly, count four slowly, and then repeat the process, *i.e.*, 15 times in a minute, keeping always to the same side. When the patient is on his face water has a chance to drain away, the tendency to faintness from shock, cold, and fright is to a certain extent obviated, and the tongue, which is apt to fall back and choke the sufferer when he is supine, falls forward when he is prone and leaves the passage free. This is artificial respiration after the method of the late Dr. Marshall Hall, and many persons have been restored by it after persevering efforts continued sometimes for an hour or more. It is a matter of common observation that drowned persons when taken out of the water are invariably laid flat on their backs, and it is certain that they could not be placed in a more dangerous position. Water in the air passages is their chief danger, and when laid on their backs there is no chance for it to escape, even if the sufferer recovers; any water left in the chest becomes a serious source of subsequent danger, and a cause of inflammation, excessive secretion, and other troubles which may prove fatal.

Ear.—To remove insects, pour in oil or warm water. To remove foreign substances, syringe gently with warm water.

Eye.—Bruised or black, close the eyelid, and bind on a linen pad soaked in brandy. To remove dirt, use the point of a lead pencil. For lime in the eye use a solution of sugar and water.

Fainting.—Keep the head low, bare the neck, and dash cold water on the face and chest, and promote circulation of fresh air.

Fits.—Keep the head raised. If snoring and face flushed, bare the neck and dash cold water on the top of the head, and apply hot water bottles to the feet. If foaming at the mouth and convulsed, bare the neck and apply smelling salts, and prevent the sufferer from hurting himself until again conscious.

Flesh Wounds.—Wash with clean water, apply lint soaked in water, and bind round with a handkerchief.

Frost Bites.—Rub with snow, or pour iced water on to the part, until the colour changes and a stinging pain comes. If the frozen part turns black next day, a poultice should be applied.

Insensibility from Wounds or Blows on the Head.—Send the sufferer to the hospital, keeping him on his back, with his head raised and his neck bared.

Insensibility from breathing foul gas or from being buried in falls of earth.—Proceed as in case of drowning.

Nose-Bleeding.—This may sometimes be stopped by pressing with the finger on the cheek near the nose; or syringe the nostril well with hot water, and immediately afterwards syringe it with iced water.

Poisoning.—Promote vomiting by tickling the throat, or by swallowing a cupful of warm water mixed with a teaspoonful of mustard; and swallow about a pint of sweet oil, which will quickly neutralize nearly all poisons.

Rupture.—Push the part back with flat hand, and apply a cold wet cloth pad. Keep the sufferer on his back.

Scalds.—Proceed as in the case of burns.

Shin Wounds.—Apply a linen pad soaked in cold water, and bind round with linen.

Skin.—For wounded or torn skin, wash with cold water, and apply either boracic lint or a linen pad soaked in a solution of boracic acid powder and water. For itching irritation of the skin, rub on ointment composed of equal parts of boracic acid powder and glycerine, and dust over with dry boracic acid powder. For prickly heat and skin eruptions induced by heat and sea-air, sponge with hot bran and water, and afterwards rub on a lotion containing coal-tar and carbolic acid.

Snake-Bites.—Proceed as in the case of dog-bites.

Sprains.—Foment with hot water.

Stings of Bees, Wasps, and Gnats.—Apply a few drops of liquid ammonia, which, if applied immediately, will destroy the poison of the sting, and relieve the pain. In the absence of ammonia, apply a pad of linen soaked in vinegar.

Sunstroke.—Apply ice or iced water to the head, and keep the sufferer in a cool place. In the absence of ice, douche, or spray, the head with cold water from a hose or watering-can.

Medical aid should be obtained as quickly as possible in all cases of poisoning, injury, and accident, as delay may be fatal.

THE FACTORIES ACT, 1937.

THIS Act comes into operation on July 1st, 1938, and supersedes the Acts of 1901 and 1907. The complete Act occupies some 145 pages and can be obtained from H.M. Stationery Office, Kingsway, price 2/6, or by post, 2/9. Part II is of particular interest to " The Works' Manager," and deals with safety provisions, fencing of machinery, precautions with respect to explosive and inflammable materials, steam boilers, air receivers and other important matters.

Section 29 states that: Every steam boiler, whether separate or one of a range:

(*a*) shall have attached to it—

(i) a suitable safety valve, separate from any stop-valve, which shall be so adjusted as to prevent the boiler being worked at a pressure greater than the maximum permissible working pressure and shall be fixed directly to, or as close as practicable to, the boiler;

(ii) a suitable stop-valve connecting the boiler to the steam pipe;

(iii) a correct steam pressure gauge connected to the steam space and easily visible by the boiler attendant, which shall indicate the pressure of steam in the boiler in pounds per square inch, and have marked upon it in a distinctive colour the maximum permissible working pressure;

(iv) at least one water gauge of transparent material or other type approved by the chief inspector to show the water level in the boiler, and, if the gauge is of the glass tubular type and the working pressure in the boiler normally exceeds forty pounds per square inch, the gauge shall be provided with an efficient guard but not so as to obstruct the reading of the gauge;

(v) where it is one of two or more boilers, a plate bearing a distinctive number which shall be easily visible; and

(*b*) shall be provided with means for attaching a test pressure gauge; and

(*c*) unless externally fired, shall be provided with a suitable fusible plug or an efficient low-water alarm device:

Provided that sub-paragraph (ii) of paragraph (*a*) of this subsection shall not apply with respect to economisers, and sub-paragraphs (iii), (iv) and (v) of paragraph (*a*), and paragraphs (*b*) and (*c*) of this subsection shall not apply with respect to either economisers or superheaters.

(2) For the purposes of the last foregoing subsection, a lever-valve shall not be deemed a suitable safety valve unless the weight is secured on the lever in the correct position.

(3) No person shall enter or be in any steam boiler which is one of a range of two or more steam boilers unless—

(*a*) all inlets through which steam or hot water might otherwise enter the boiler from any other part of the range are disconnected from that part; or

(*b*) all valves or taps controlling such entry are closed and securely locked, and, where the boiler has a blow-off pipe in common with one or more other boilers or delivering into a common blow-off vessel or sump, the blow-off valve or tap on each such boiler is so constructed that it can only be opened by a key which cannot be removed until the valve or tap is closed and is the only key in use for that set of blow-off valves or taps.

(4) Every part of every steam boiler shall be of good construction, sound material, adequate strength, and free from patent defect.

(5) Every steam boiler and all its fittings and attachments shall be properly maintained.

(6) Every steam boiler and all its fittings and attachments shall be thoroughly examined by a competent person at least once in every period of fourteen months, and also after any extensive repairs:

Provided that, in the case of any range of boilers used at the date of the passing of this Act for the purposes of a process requiring a continuous supply of steam, any stop-valve on the range which cannot be isolated from steam under pressure need only be examined so far as is practicable without such isolation, but this proviso shall cease to have effect as soon as a reasonable opportunity arises for installing devices to enable the valve to be so isolated and, in any case, at the expiration of a period of three years from the passing of this Act.

(7) Any examination in accordance with the requirements of the last foregoing subsection shall consist, in the first place, of an examination of the boiler when it is cold and the interior and exterior have been prepared in the prescribed manner, and secondly, except in the case of an economiser or superheater, of an examination when it is under normal steam pressure, and the two parts of the examination may be carried out by different persons; the examination under steam pressure shall be made on the first occasion when steam is raised after the examination of the boiler when cold, or as soon as possible thereafter, and the person making the examination shall see that the safety valve is so adjusted as to prevent the boiler being worked at a pressure greater than the maximum permissible working pressure.

(8) A report of the result of every such examination in the prescribed form and containing the prescribed particulars (including the maximum permissible working pressure) shall, as soon as practicable and in any case within twenty-eight days of the completion of the examination, be entered in or attached to the general register, and the report shall be signed by the person making the examination, and if that person is an inspector of a boiler-inspecting company or association, countersigned by the chief engineer of the company or association or by such other responsible officer

of the company or association as may be authorised in writing in that behalf by the chief engineer.

For the purposes of this subsection and the succeeding provisions of this section relating to reports of examinations, the examination of a boiler when it is cold and its examination when it is under steam pressure shall be treated as separate examinations.

(9) No steam boiler which has previously been used shall be taken into use in any factory for the first time in that factory until it has been examined and reported on in accordance with the last three foregoing subsections; and no new steam boiler shall be taken into use unless there has been obtained from the manufacturer of the boiler, or from a boiler-inspecting company or association, a certificate specifying the maximum permissible working pressure thereof, and stating the nature of the tests to which the boiler and fittings have been submitted, and the certificate is kept available for inspection, and the boiler is so marked as to enable it to be identified as the boiler to which the certificate relates.

(10) Where the report of any examination under this section specifies conditions for securing the safe working of a steam boiler, the boiler shall not be used except in accordance with those conditions.

(11) The person making the report of any examination under this section, or, in the case of a boiler-inspecting company or association, the chief engineer thereof, shall within twenty-eight days of the completion of the examination send to the inspector for the district a copy of the report in every case where the maximum permissible working pressure is reduced, or the examination shows that the boiler cannot continue to be used with safety unless certain repairs are carried out immediately or within a specified time.

(12) If the person employed to make any such examination fails to make a thorough examination as required by this section or makes a report which is false or deficient in any material particular, or if the chief engineer of any boiler-inspecting company or association permits any such report to be made, he shall be guilty of an offence and liable to a fine not exceeding fifty pounds, and if any such person or chief engineer fails to send to the inspector for the district a copy of any report as required by the preceding subsection, he shall be guilty of an offence.

(13) If the chief inspector is not satisfied as to the competency of the person employed to make the examination or as to the thoroughness of the examination, he may require the boiler to be re-examined by a person nominated by him, and the occupier shall give the necessary facilities for such re-examination. If as a result of such re-examination it appears that the report of the examination was inadequate or inaccurate in any material particular, the cost of the re-examination shall be recoverable from the occupier summarily as a civil debt, and the report of the re-examination purporting to be signed by the person making it shall be admissible in evidence of the facts stated therein.

(14) In this Part of this Act, the expression " maximum permissible working pressure " means, in the case of a new steam boiler, that specified in the certificate referred to in subsection (9) of this section and in the case

of a steam boiler which has been examined in accordance with the provisions of this section, that specified in the report of the last examination; and the expression " steam boiler " means any closed vessel in which for any purpose steam is generated under pressure greater than atmospheric pressure, and includes any economiser used to heat water being fed to any such vessel, and any superheater used for heating steam.

(15) This section shall not apply to any boiler belonging to or exclusively used in the service of His Majesty, or to the boiler of any ship or of any locomotive which belongs to and is used by any railway company.

30.—(1) Every steam receiver, not so constructed and maintained as to withstand with safety the maximum permissible working pressure of the boiler or the maximum pressure which can be obtained in the pipe connecting the receiver with any other souce of supply, shall be fitted with—

(*a*) a suitable reducing valve or other suitable automatic appliance to prevent the safe working pressure being exceeded; and

(*b*) a suitable safety valve so adjusted as to permit the steam to escape as soon as the safe working pressure is exceeded, or a suitable appliance for cutting off automatically the supply of steam as soon as the safe working pressure is exceeded; and

(*c*) a correct steam pressure gauge, which must indicate the pressure of steam in the receiver in pounds per square inch; and

(*d*) a suitable stop valve; and

(*e*) except where only one steam receiver is in use, a plate bearing a distinctive number which shall be easily visible.

The safety valve and pressure gauge shall be fitted either on the steam receiver or on the supply pipe between the receiver and the reducing valve or other appliance to prevent the safe working pressure being exceeded.

(2) For the purpose of the provisions of the foregoing subsection, except paragraph (*e*), any set of receivers supplied with steam through a single pipe and forming part of a single machine may be treated as one receiver, and for the purpose of the said provisions, except paragraphs (*d*) and (*e*), any other set of receivers supplied with steam through a single pipe may be treated as one receiver:

Provided that this subsection shall not apply to any such set of receivers unless the reducing valve or other appliance to prevent the safe working pressure being exceeded is fitted on the said single pipe.

(3) Every part of every steam receiver shall be of good construction, sound material, adequate strength, and free from patent defect.

(4) Every steam receiver and its fittings shall be properly maintained, and shall be thoroughly examined by a competent person, so far as the construction of the receiver permits, at least once in every period of twenty-six months.

(5) A report of the result of every such examination containing the prescribed particulars (including particulars of the safe working pressure) shall be entered in or attached to the general register.

(6) Every steam container shall be so maintained as to secure that the outlet is at all times kept open and free from obstruction.

(7) In this section the following expressions have the meanings hereby respectively assigned to them, that is to say:

" safe working pressure " means, in the case of a new steam receiver, that specified by the maker, and in the case of a steam receiver which has been examined in accordance with the provisions of this section, that specified in the report of the last examination;

" steam receiver " means any vessel or apparatus (other than a steam boiler, steam container, a steam pipe or coil, or a part of a prime mover) used for containing steam under pressure greater than atmospheric pressure;

" steam container " means any vessel (other than a steam pipe or coil) constructed with a permanent outlet into the atmosphere or into a space where the pressure does not exceed atmospheric pressure, and through which steam is passed at atmospheric pressure or at approximately that pressure for the purpose of heating, boiling, drying, evaporating or other similar purpose.

31.—(1) Every air receiver shall—

(*a*) have marked upon it so as to be plainly visible the safe working pressure; and

(*b*) in the case of a receiver connected with an air compressing plant either be so constructed as to withstand with safety the maximum pressure which can be obtained in the compressor, or be fitted with a suitable reducing valve or other suitable appliance to prevent the safe working pressure of the receiver being exceeded; and

(*c*) be fitted with a suitable safety valve so adjusted as to permit the air to escape as soon as the safe working pressure is exceeded; and

(*d*) be fitted with a correct pressure gauge indicating the pressure in the receiver in pounds per square inch; and

(*e*) be fitted with a suitable appliance for draining the receiver; and

(*f*) be provided with a suitable manhole, handhole, or other means which will allow the interior to be thoroughly cleaned; and

(*g*) in a case where more than one receiver is in use in the factory, bear a distinguishing mark which shall be easily visible.

(2) For the purpose of the provisions of the foregoing subsection relating to safety valves and pressure gauges, any set of air receivers supplied with air through a single pipe may be treated as one receiver:

Provided that, in a case where a suitable reducing valve or other suitable appliance to prevent the safe working pressure being exceeded is required to be fitted, this subsection shall not apply unless the valve or appliance is fitted on the said single pipe.

(3) Every air receiver and its fittings shall be of sound construction and properly maintained.

(4) Every air receiver shall be thoroughly cleaned and examined at least once in every period of twenty-six months:

Provided that in the case of a receiver of solid drawn construction—

(*a*) the person making any such examination may specify in writing a period exceeding twenty-six months but not exceeding four years within which the next examination is to be made; and

(*b*) if it is so constructed that the internal surface cannot be thoroughly examined, a suitable hydraulic test of the receiver shall be carried out in lieu of internal examination.

Every such examination and test shall be carried out by a competent person, and a report of the result of every such examination and test, containing the prescribed particulars (including particulars of the safe working pressure), shall be entered in or attached to the general register.

(5) In this section the expression " air receiver " means—

(*a*) any vessel (other than a pipe or coil, or an accessory, fitting or part of a compressor) for containing compressed air and connected with an air compressing plant;

(*b*) any fixed vessel for containing compressed air or compressed exhaust gases and used for the purpose of starting an internal combustion engine; or

(*c*) any fixed or portable vessel (not being part of a spraying pistol) used for the purpose of spraying by means of compressed air any paint, varnish, lacquer or similar material; or

(*d*) any vessel in which oil is stored and from which it is forced by compressed air:

Provided that the provisions of paragraph (*e*) of subsection (1) of this section shall not apply to any such vessel as is mentioned in paragraph (*c*) or paragraph (*d*) of this subsection.

32. The chief inspector may by certificate except from any of the provisions of the last three preceding sections of this Act any class or type of steam boiler, steam receiver, steam container or air receiver to which he is satisfied that such provision cannot reasonably be applied. Any such exception may be unqualified or may be subject to such conditions as may be contained in the certificate.

INDEX.

ABSOLUTE pressure, 15
Accidents to workmen, 433, 434
Accumulator, the, 120
Acid test for gold and silver, 355
—— for iron and steel, 360
—— test for steel, 266
Acid-proof cements, 368
Acids, metals to resist, 247, 248, 250, 255
Actual horse-power of boilers, 175
—— horse-power of engines, 5, 14, 71, 73
—— horse-power of pumps, 103
—— horse-power of shafts, 150
—— of rope-gearing, 131
—— of wheel-gearing, 134
Adamson's flanged seams, 172, 186
Adhesive power of locomotive engines, 66
Admiralty gun-metal, 250
Admission line of diagrams, 10
Advance of the cut of tools, 224
Air admitted above the fire in boilers, 172
—— cooling of pipes by, 210
—— for apartments, 210
—— for barracks, 210
—— for candle-burning, 212
—— for churches, 212
—— for coal-burning, 195
—— for hospitals, 218, 219
—— for mines, 213
—— for oil-burning, 212
—— for prisons, 212
—— for public buildings, 212
—— —— per head, 212
—— for respiration, 212
—— for transpiration, 212
—— for ventilation, 212, 213
—— -pumps, 55-58
—— pump-efficiency, 58
—— -pump valves, 58
—— vessel for pumps, 98, 103
—— warm, for heating, 211
—— weight of, 213
Air, increase of volume of, by heat, 213
——, mean temperature of, 432
——, properties of, 432
Alloys, for fusible plugs, 253
—— fusible, 254, 256
—— melting point of, 256
—— of copper and tin, 243, 251
—— of tin and copper, 252, 255
—— specific gravity of, 356
—— strength of, 243, 251, 344
Alloys, various, 243-255
—— weight of, 311, 321, 325-339, 346
Aluminium, 331-333, 346, 357, 400, 406
—— brass, weight of, 334
—— bronzes, weight of, 334
—— bronze, 243, 334, 344, 390
—— drilling speed for, 217
—— light alloys of, 249, 251
—— magnesium alloys, 402
—— nickel, weight of, 334
—— sheet, weight of, 331
—— solder, 258
—— tubes, weight of, 332
Analysis of liquid fuels, 399
Angle iron beams, 287
—— iron, length to make a hoop, 312
—— iron, strength of, 344
—— iron, weight of, 314
—— of clearance of lathe tools, 219
—— of cutting of lathe tools, 219
—— of lathe centres, 219
—— of safety-valve seats, 192
—— steel, weight of, 316
Angular velocity, 128
Animals, power and weight of, 4
—— floor and cubical space for, 212
—— tested performances of, 428, 430
Annealing metals, 264, 265
Anti-corrosive metal, 247, 248, 252, 255
—— -corrosive paint, 374
—— -friction grease, 365
—— -friction metal, 251, 252
—— -friction metal plates, weight of, 329
—— -friction metal tubes, weight of, 338
—— metals, weight of, 329
Antimony, 345, 356, 406
Antimonial lead, 251, 253
Antique bronze, 262
—— bell-metal, 248
Approximates, decimal, 426, 427
Aquarium cement, 368
Area of chimneys, 195
—— of cylinders, 38, 63, 69, 434
—— of cylinders for compound engines, 63
—— of egg-shaped sewers, 427
—— of exhaust-pipe, 29, 40
—— of safety-valve, 191
—— of steam-pipe, 29, 40
—— of steam-port, 29
Arms of pulleys, curved, 159
—— of pulleys, straight, 159
—— of wheel gearing, 226
Arsenic bronze, 244, 249
Art-metal, 246, 247, 248
Asbestos covering for pipes, 120

Ash, strength of, 345, 390
Atmospheric air, volume of, 213
Atomic weight of elements, 417
Axle grease, 365
—— locomotive, 72

BACK pressure, 12, 21
Baffle plate of boilers, 173
Balancing moving parts of engines, 38
Balls, cast iron, weight of, 315
—— for governors, 30, 33
—— of various metals, to find the weight of, 315
Bands, cotton, 163
—— leather, 162, 163
—— rope, 131, 132
—— wire-rope, 164
Band-saws, speed of, 220
Band-saw blades, strength of, 220
Barrels, contents of, 349
Beams, angle iron, 287
—— cast iron, 284, 288
—— flitch, breaking loads on, 293
—— wood, 284
—— wrought iron, 285
Bearings, alloys for, 243-250
—— anti-friction, 254, 255
—— friction of, 66, 146, 147
—— metals, various, 243-255
—— pressure on, 151, 245
—— of shafting, distance between, 150, 152
—— of water-wheels, 115
—— self-lubricating, 365
—— wear-resisting, qualities of, 245
Bed, engine, 49
Beech, strength of, 345, 390
Bell clappers, 251
—— metal for small bells, 245, 248, 253
—— metal for church bells, 247, 251
Bells, thickness of metal of, 251
—— weight of, 251
Belts, cements for, 373
—— cotton, strength of, 163
—— dressing for, 366
—— for damp places, 164
—— friction of, 164
—— india-rubber, 164
—— linen, 164
—— leather, rules for, 162, 163
—— leather, strength and weight of, 163
—— pulleys for leather, 159-162
—— pulleys for rope, 134
—— pulleys for wire rope, 164
—— rope, 134
—— waterproof, 164
Bends in water-pipes, effect of, 117
Bessemer steel, 109, 270, 311, 358, 380
—— steel, weight of, 311
Bevel wheels, friction of, 130
—— power of, 131, 139
—— wheels, proportions of, 124
—— wheels, to project, 125
—— wheels, weight of, 135
B. G. gauge for sheet and hoop-iron, 319
Birmingham, Stubs, American, and French, wire-gauges, 324
—— wire gauge, weights of metal to, 325
Bismuth, 255, 356, 406
Bismuth solders, 257
Blackboards, paint for, 374
Black finish for brass work, 261, 262
Blast of fans, 227
Block-tin tubes, weight of, 306
Blueing and colouring metals, 260-262
Bogie engines, 71, 73
Boilers, 169-201
—— blowing-off, 200
—— bursting-pressure of, 187, 188
—— care of, rules for, 198
—— cements for covering, 120, 372
Boiler chimneys, 179, 195, 196
Boilers, collapsing pressure of, 187
—— Cornish, proportions and weight of, 177
—— dished ends of, 174
—— egg-ended, 174, 182
—— ends, 171
—— efficiency, and evaporative performance of, 190
—— evaporative power of fuels, 169
—— factor of safety of, 188
—— feed, position of, 174
—— firebars, 197
—— fire instructions, 198
Boiler fittings, 173, 198
Boilers, flat surface staying, 173, 174
Boiler flues, 173, 195
—— flues, collapsing pressure of, 187
—— furnace, mounting, 173
—— heating surface, 175
Boilers, horse-power of Cornish, 174
—— horse-power of Lancashire, 174
—— horse-power of vertical, 175
—— hot water, 223
Boiler incrustation, 197
Boilers, flash, 190
Boilers, Lancashire, 168-169
—— locomotive, 72-75
Boilers, water-tube, 189, 190
Boiler-plates, iron, loss of strength of, at high temperatures, 281
—— -plates, nickel steel and carbon steel compared, 359
—— plates, iron, strength of, 184, 279
—— plates iron, testing, 280
—— plates, iron, weight of, 302, 309
—— plates, steel, 184, 280, 311, 359
Boilers, portable, proportions and weight of, 180
—— return tube, proportions and weight of, 182

Boiler rivets, pitch of, 300
—— rivets, test for, 281
—— rivets, weight of, 323
Boilers, riveted joints of, 184, 185, 186, 300, 301
—— rules for the weight of, 182
Boiler safety-valves, 190-194
—— scale, 197
—— setting, 173
—— shells, 169, 170
—— shells, bursting pressure of, 187, 188
—— shells, weight of, 183
—— stays, 171, 173
Boilers, staying flat surfaces of, 173, 174
—— steel, weight of, 177-183
Boiler-flue tube, strengthening rings, 172, 186
—— tubes, brass, weight of, 329, 335
—— tubes, wrought-iron, weight of, 182, 186
—— tubes, wrought-iron, lap-welded, weight of, 184, 329, 340
—— tubes, collapsing pressure of, 186
Boilers, weight of, 177-182
Boiling point of water, 167
—— of metals, 256
Bolts, nuts and washers, weight of, 303
—— for foundations, 304
—— strength of, 304
—— weight of, 303
—— Bore of guns, size of, 322
Boring machines, 219 : power for, 350
—— metals, speed for, 216, 217
Brake-Horse-Power, 5
—— cost of working engines per, 79
—— of petrol engines, 430
Brakes, friction, 5-8
—— friction of wood blocks for, 78
Brands of pig iron, 241
Brass, alloys, 243-252
—— aluminium, 332
—— bars, weight of, 243, 321
—— black finish for, 262, 361
—— bronzing, 262
—— burnishing, 259
—— casting, 212, 213
—— colouring, 262
—— dipping, 262
—— effect of rolling, 248
—— finishing, 259
—— foundry, 242
—— foundry receipts, 364
—— furnace, 212
—— lacquering, 262, 263
—— malleable, 244
—— melting, 236
—— mixtures of metal for, 243-245
—— naval, 218, 326, 327
—— polishing, 257
—— red, 250
—— sheet, 250, 231, 310
—— speed for cutting, 216
—— strength of, 243, 252, 325, 341, 390
—— tubes, 249, 329, 335
Brass, various mixtures of, 243-252
—— weight of, 243, 311, 312, 321, 325
—— white, 246, 252
—— to whiten, 262
—— wire, 248, 250, 344
—— wire, strength of, 243, 344
—— wire, weight of, 321
Brasses, 243-245
Breaking strains, 135, 169, 170, 314, 354, 345, see also Tensile Strength
Breast water-wheels, 114
Bricks, 388, 389, 391, 392
Brickwork, 388-392
Brightening metals, 259, 342
British Association, gauge for screws, 270
—— —— threads, 411
—— Standard bolts, 408
—— —— fine threads, 409
—— —— gas threads, 409
—— —— threads for copper, 412
Bronze, aluminium, 213, 333, 334, 390
—— bearing metal, 243-250, 253
—— burnishing, 259
—— bush metal, 243-250, 253
—— castings, 242, 243
coins, 355
—— colouring, 262
—— finishing, 259
—— for piston rings, 247, 248
—— for pumps, &c., 217, 248, 252
—— lacquering, 262, 263
—— manganese, 246, 328
—— nickel, 246, 328
—— ordinary, 246-251, 328
—— phosphor, 218
—— polishing, 259
—— silicon, 248, 328
—— Silicium, 241
——, special mixtures of metal for various purposes, 246-255
—— statuary, 213
—— strength of, 243, 244, 251, 311, 390
—— weight of, 243, 311, 328, 333, 334
Bronzing metals, 262
Brunswick black, 375
Buffs for polishing metals, 259
Building materials, 341, 345, 388, 392
Buildings, brickwork for, 388, 389
—— mortar, cement and concrete for, 388-390
—— strength of cements and concrete for, 391
—— strength of bricks for, 391, 392
—— working loads on foundations for, 389
—— working loads on metals and woods for, 390
Bulk or stowage capacity of various materials, 348, 349
Burnishing steel and other metals, 259
Burns, and accidents, 433
Bursting pressure of boilers, 187, 188
—— pressure of cylinders, 109
—— pressure of hydraulic cylinders, 119

Bursting pressure of lead pipes, 314
Bursting pressure of spherical shell, 187
Bursting pressure of water pipes, 109, 110
—— pressure of pipes and cylinders of various metals, 109
Bushes, special metals for, 243-250
Butt-strips and butt-joints, 301

CABLES, 283
Cadmium, 356, 406
Calculations for pumps, 98, 113
Canals, flow of water in, 116
Canvas belting, 164
—— to waterproof, 366
Capacity of pumps, 90, 95
—— round tanks, 415
Carbon, 380, 386
—— percentage of, in steel, 268
—— -steel, composition and weight of, 359
Carbonic acid gas, specific gravity of, 347
Care of steam boliers, 198-202
Cart-axle boxes, alloy for, 252
Carts, resistance to traction, 4, 431
Casehardening, 264
Casks, contents of, 349
Casts, composition for taking, 253, 254, 364
Cast aluminium, 331
Cast-iron, notes on, 109, 110, 240, 344, 357
—— balls, weight of, 315
—— bars, tests for, 110, 246
—— beams, 284
—— cements for, 373
—— circular plates, weight of, 320
—— chilled, 241
—— columns, 298, 299
—— composition of, 386
—— cylinders, metal for, 241
—— cylinders, weight of, 317, 318
—— fire bars, 197
—— girders, 287, 288
—— pillars, 299
—— pipes, bursting pressure of, 109
—— pipes, notes on, 110
—— pipes, rules for, 109, 110
—— flange pipes, weight of, 111, 112
—— plates, weight of, 312, 320
—— socket pipes, contents of, 113
—— socket pipes, lead for joints of, 110
—— socket pipes, pressure in, 110
—— socket pipes, testing, 110
—— socket pipes, weight of, 111
—— strength of, 109, 110, 246, 344, 390
—— various mixtures of, 241
—— weight of a square foot of, 312
Cast-steel castings, 135, 390
Casting brass and gun-metal, 242
Casting iron, various mixtures of metal for, 241
—— iron, foundry receipts, 364
Castings, brass and gun-metal, 242-250
Castings, contraction of, 379
—— measuring patterns for, 296
—— rules for finding the weights of, 296
—— steel, 135
Cementation, 358
Cements and concrete for buildings, strength of, 391
—— for cast-iron, 373
—— for the laboratory and workshop, over 100 in number, 368-372
Centre distance of bearings, 396
—— of gyration, 128
—— -weighted governors, 32, 33
Centres of lathes, 230
—— of rivets of boilers, 310
—— of rivets of girders, 289
—— of stay-bolts, 174
Centrifugal force, 30 : of fly-wheels, 52
—— pumps, 96
Centripetal force, 30
Chain slings safe working load, 398
Chains and ropes, 282-284
Change-wheels, tables of, for screw cutting, 233-239
—— weight of, 315
Channel-steel, weight of, 316
Channels and pipes, flow of water in, 97, 116, 353
Chemical substances, description of, 385-387
Chilled castings, mixtures of metal for, 241
—— rolls, metal for, 241
—— rolls, turning, 219
Chimneys for factory boilers, power of and rules for, 195, 196
—— for vertical boilers, 179
Chisels, to harden, 267
Chisel-steel, weight of, 308
Circles, 426
Circular iron plates, 302, 320
—— pitch, 407
—— saw benches, speed and horse-power of, 220
—— saws, speed of, 220
Circumferential velocity, 128
Cisterns, contents of, 91, 95, 351, 352
—— cements for, 373
—— stock sizes of, 351, 352
Clay covering for pipes, &c., 120, 338
Cleaning boilers, 200
—— brass and silver, 364
Clearance in cylinders, 20, 42
Cloth, to waterproof, 366
Clothing for cylinders, 39, 367
—— for pipes, 120, 372
Coal, 168, 380
Cobalt, 406
Cocks, proportions of, 105
—— and valves for steam, metal for, 246, 250
—— and valves for water, metal for, 247, 248, 249
Coinage, 355
Coins, metal for, 355

Coins, weight of, 355
Coke, 169 ; for melting cast-iron, 216
Collapsing pressure of boiler flue tubes, 187
Colouring drawings, 377
—— metals, 260-264
Column of water, weight of, in pump barrels, 93
Columns, hollow, 299
—— of water, 94, 98, 106, 113
—— solid, 299
Combustion of fuels, 168
Composition for covering steam boilers and pipes, 120, 372
—— for scale in steam boilers, 197
—— for taking impressions and casts, 364
—— of alloys, 243-255
—— of fuels, 168
—— of glass, 386
—— of iron, 386
—— of lacquers, 263
—— of paints, 360, 374
—— of sea-water, 202
—— of slag of furnaces, 387
—— of steel, 359
—— of water, 93
—— of varnishes, 374, 375
Composition pipes, weight of, 306
Compound engines, 54-64
—— girders, 291
—— locomotives, 73-75
Compressed bronze, 244
—— steel, 118, 359
—— steel, weight of, 330
Compression line of diagrams, 10, 13
—— of metals and materials, resistance to, 240, 279, 299, 344, 345, 390-392
—— of steam, 13, 20
Concrete and cement for buildings, strength of, 391
Condensation in pipes cooled by water, 214
—— in steam cylinders, 19, 20
Condensation-reservoirs, 56
Condenser jet, 55, 56
Condensers, surface, 57
Condensing engines, 55
—— engines, nominal horse-power of, 5
Condensing water, 56
Conducting power of metals for heat, 206
Conduction of metals for electricity, 276
Conductor, lightning, 196
Connecting rods, 47-49
Consumption of coal by engines, 69, 74, 75, 169
—— of coal in hot-water boilers, 223
—— of gas by gas-engines, 83-85
—— of oil by oil-engines, 86
—— of petrol by petrol-engines, 430
—— of steam by locomotives, 74, 75
Contents of balls, 298
—— of barrels, 349
—— of boilers, 176
—— of cisterns, 94, 95, 351, 352
—— of cone, 298
Contents of cylinders, 98, 103, 113
—— of pipes, 95, 112, 113
Contents of wells, 113
Contraction of metals in casting, 379
Convection, 167
Conversion of area, 408
—— of energy, 411
—— of mass, 415
—— of power, 397
—— of pressure, 418
—— of steel, 358
—— of volume, 412
Converting the weight of one metal into that of another, 297
Cooling iron pipes, 222, 226
—— water, 56
Copper, 406
——, alloys of, 249-252
—— bars, weight of, 321
—— blanched, 246
—— bronzing, 262
—— casting, 249
—— flanges for pipes, alloy for, 252
—— notes on, 327, 355
—— pipes, weight of, 330, 336
—— plates, weight of, 310, 312, 325
—— sheets, weight of, 310, 312
—— speed for turning, 217
—— strength of, 243, 251, 337, 364, 390
—— tubes, 330, 336, 337
—— tubes, hardened, 337
—— tubes, strength of, 337
—— tubes, weight of, 330, 336
—— wire, strength of, 344
Cord of wood, 212, 389
Cornish boilers, 170-177
—— boilers, contents of, 176
—— evaporative performance of, 190
Corrodibility of metals, relative, 360
Corrosion, prevention of, 360
Corrugated iron, weight of, 306
—— furnaces, 187
—— roofing, 390
Cotters and gibs, 48
—— for bolts, 304
Cotton belting, strength of, 163
—— waste, stowage capacity of, 348
Couplings, for shafting, 153-155
—— claw, 155.—Friction-cone, 155
—— disengaging, 155
—— flanged, 152, 153
—— muff, 152, 153, 154
Covering, non-conducting, for pipes, &c., 120
—— for boilers, 372
—— for cylinders, 367
Cowsheds, space in, 212
Crab gearing, 125
Crane gearing, 131, 132
—— shafts, 149
Crank, 43.— pin, 44
—— shafts, 43, 148, 149, 152
Crank-shafts, friction of, 66

Cross heads, 45-47
Crucibles, 364
Crushing strain of materials, 240, 279, 293, 299, 344, 345, 390-393
—— strength of bricks, 391, 392
—— strength of cements and concrete, 391
Cupola, 381
Curve, expansion, 12
—— theoretical, 9
Cushioning, 21
Cutlers' cement, 370
Cutters, to harden and temper, 270
—— for wood-working machines, 220
Cutting angle of lathe tools, 218
—— metals, 216, 217, 219, 232
—— metals, power required for machinery for, 350
—— screws, 229-239
—— wheels, 227-229
—— wheels, price for, 232
—— wood, power required for machinery for, 220
Cylinder area, 38, 63, 69, 434
—— condensation, 19, 20
Cylinders, bursting pressure of, 109
—— cast-iron, weight of, 317, 318
—— contents, of, 95
—— hydraulic, 119
—— mixtures of metal for, 241
—— steam, proportions of, 38, 63, 69
—— strength of, 109
—— thickness of, 39
Cylindrical steam boilers, 169

DEAD loads, 290
Deal, strength of, 315, 390
Deal frames, speed of, 220
Decimal approximates, 426, 427
—— equivalents, 313, 423-426
Delivery pipes of pumps, 102
Density of blast fans, 227
Depreciation of factories, 379
—— of machinery, 379
Diagrams indicator, 9-15
Diameter of cylinder, 38, 63, 69, 424
—— of a pump, 101
Diametral pitch, 141, 144, 145, 407
Diesel Oil Engine, 86
Diminution of strength of iron at high temperatures, 281
Discharge of gas pipes, 381
—— of sewers, 119, 354
—— of water by pumps, 98, 103, 107, 108, 352, 353
—— of water channels, 116, 119
—— of water pipes, 97, 116, 117, 353
—— of water through an orifice, 115
Discount table, 421
Dished ends of boilers, 174
Dissolving metals, 262, 355
Distance of bearings of shafting, 150, 152
Distribution of heat in boilers, 169
Dome of boilers, 175
Domestic water-supply, 96
Double Helical-toothed Wheels, 132, 133
—— friction of, 130
Double and treble-threads of screws, 236
Drains, discharge of, 119, 354
—— fall of, 117
Draught of chimneys, 195
Drawings, to colour, 377 : varnish for, 376
Drilled boiler plates, 185
Drilling glass, 266
—— hard steel, 265
—— metals, power required for, 350
—— various metals, speeds for, 217
—— work, 219
Drills, plain, speeds for, 217
—— to harden, 265, 267
—— twist, speed for, 217
Driving power of belts, 393, 394
Dry rot, paint for, 374
Drying rooms, heating, 210
Dubbing, 366
Ductibity of metals, 257
Duralumin, 401
Dusting for moulds, 364
Dwelling-rooms, heating, 210
—— space, 212, 213
Dwellings, ventilating, 212
—— warming, 210
Dynamometers, 5-8

EBONIZING wood, 375
Ebullition, 167
Eccentric, 27, 44
—— strap and rod, 44, 45
Economical working, 22
Effective pressure, 15, 63
Efficiency of boilers, 190
—— of pumps, 3, 58, 104
Egg-shaped sewers, 427
Electric motors, cost of running, 418
—— ——, cost of working, 79
Electrical resistance—alloy, 246, 249
Electricity, power of metals to conduct, 276
Emission of heat from pipes, 214, 215
Emptying boilers, 200
Enamel glaze for pans, 373
End plates of boilers, 171
Engine-bed, 49
——, condensing, 54-63
—— foundations, 50
Engines, compound, 60-64
—— gas, 79, 83-85
—— locomotive, 66-75
—— oil, 79, 86
—— petrol, 430
—— portable, hire of, 151
—— proportions of, 34-71
—— stationary, 34-64

Engines, triple expansion, 64, 65
Equivalents, decimal, 313, 423-426
Estimates, data for, 219, 227
Evaporation of boilers, to ascertain, 175
Evaporative efficiency of boilers, 190
—— power of fuels, 168, 169, 380
—— power of gas, 216
Exhaust line of diagrams, 10, 12
—— pipe, 29, 40
—— port, 29, 40
Expansion curve, 9, 12
—— hoops for boiler flue tubes, 172, 176
—— of hot-water pipes, 212
—— longitudinal, of boiler flue-tubes, 172
—— of liquids by heat, 206
—— of metals by heat, 206
—— of steam, 9, 12, 17, 18, 21, 168
—— of steam-pipes, 212
—— of steam, ratio of, 15, 21
—— of steam, theoretical curve of, 9
—— of water by heat, 202
—— of water in freezing, 91
ratio of, 15, 21, 62
—— seams for flue-tubes, 172, 186
Expansive work of steam, 18
Express locomotives, 71-75

FACTORS of safety, 187, 188, 279, 280, 284, 285, 290, 293, 304, 383
Factory chimneys, rules for, 195, 196
—— chimneys, horse-power of, 195
Factories, depreciation of, 379
—— warming by hot water and steam, 208-212
Fall of drains, pipes, sewers, and rivers, 117
—— of water, force of, 114
Falling bodies, 378
Fans, speed and proportions of, 227
Feed of cut of machine-tools, 218
—— pipe, position of in boilers, 174
—— -pump for non-condensing engines, 45
—— -water, heating, 174
—— water, supply, 174, 198
Felt, hair for covering pipes, &c., 120
Final pressure of steam, 15, 63
Finishing brass and gun-metal, 259
—— iron and steel, 259
—— iron castings, 259, 374
Fire bars for boilers, 197
—— box, 176
—— bridge of boilers, 173
Firing boilers, 198
Fitter's work, price of, 221
Fittings for boilers, 173, 198
——, steam, metal for, 249, 250
Flanged seams for boilers, 172, 186
Flash-boilers, efficiency and revaporative power of, 190
Flat surfaces, staying, 173
Flexible paint, 374
Flitch plate girders, 284, 293
Flitch-beams, breaking loads on, 293
Floors, to polish and stain, 376
Florentine art-bronze, 248
Flow of sewage in pipes, 119, 354
—— of water in pipes, 97, 117, 353
—— of water in rivers and channels, 116, 118
—— of water, memoranda for, 118, 119
—— of water over weirs, 117
Flues for boilers, 171, 172, 184, 195
—— for boilers, collapsing pressure of, 187
—— corrugated, 187
Flux for brass, 343
—— for solders, 259
Fly-wheels, weight of, 50
—— velocity, strength and energy of, 50-54
Force, tractive, of locomotive engines, 67, 71
—— -pumps, 45, 100, 102, 130
Forge tests for iron and steel plates, 280
Fossil meal covering for pipes, 120
Foundation bolts, 304
—— for steam engines, weight of, 50
Foundations, loads on, 389
Foundry, brass, memoranda, 242, 343
—— iron, memoranda, 240, 343
—— receipts, 364
Fractional parts of a foot, 424
—— parts of a hundredweight, 426
—— parts of an inch, 423
—— parts of a millimetre, 414
—— parts of a pound avoirdupois, 425
Freezing, expansion of water in, 91
—— mixtures, 367
—— point of various liquids, 256
French horse-power, 421, 422
—— measures and English equivalents, 415-423
—— measures, scale for, 414
—— pitch of screws, rules for cutting, 232, 239
—— polish for wood, 375
—— unit of heat, 421
—— unit of work, 421
—— weights, 421, 422
—— words for English engineering terms, 392-414
Friction of toothed wheels, 130
—— cone-coupling, 155
—— cone-keys, 159
—— -brakes, various, 5-8
—— of crank-shafts, 66
—— of bearings, 147
—— of leather belts, 162, 164
—— of rope-belts, 135
—— of ropes in grooves, 135
—— of ropes on pulleys, 164
—— of shafts, 146
—— of slide-valves, 27
—— of water in pipes, 116, 117
—— of wood brake-blocks, 78
—— power absorbed by, 146
—— resistance to, 146
Frictional gearing, 133
Fuel, combustion of, 168

Fuel, consumption of per indicated horsepower, 169
Fuels, 86, 168, 169, 380, 430
Furnace, air in, 173, 195
—— area of, for wood burning, 202
—— brass, 242
—— corrugated, 187
—— door, 173
—— mouthpiece, 173
—— slag, composition of, 387
—— ventilation, 213
Furnaces, cement for, 339
—— temperature of, 73, 256
Fusible alloys, 254, 256
plug alloys, 254
— plug, directions for use of, 201

GALLONS of water delivered by pipes, 97, 116, 353
—— of water, per stroke of pumps, 103, 353
—— measurement by, 93, 94, 353
Galloway boiler, 176
—— tubes, 176, 177
Galvanized iron cisterns, usual sizes of, 351, 352
—— iron sheets, 323
—— iron wire, 319
—— pipes, 339
—— Galvanizing iron, 261
Gas, coke, specific gravity of, 316
—— discharge, pressure, and power of, 381
—— engines, 79, 84–85
—— fittings and tubes, weight of, 305
—— fittings, brass, alloy for, 247
—— pipes and tubes, weight of, 305, 339, 340
—— pipes, proportions of, 112, 274
—— producers, 79–82
—— threads, 274, 275
Gases, expansion of, by heat, 206
—— weight of, 347
Gauge, B.G., for sheets and hoops, 309
—— Birmingham and other, 321
—— British Association for screws, 270
—— of wood screws, 315
—— the standard wire-gauge, 309, 425
—— zinc, the, 322
Gearing, belt, 172, 173
—— for cranes, 131, 132
—— for well frames, 102
—— frictional, 133
—— metal for, bronze, 249, 250
—— metal for, iron, 231
—— rope, rules for, 132, 133, 134
—— rope, weight of, 134
—— speed of different kinds of, 125
—— steel, 135
—— toothed wheel, 123–145
—— toothed wheel, weight of, 135–145
Gibs and cotters, 48
Gilding brass and other metals, 263
Gilding metal, 247
Girders, box, wrought-iron, 285
—— cast iron, 287, 288
—— compound, 291
—— riveted steel, 292
—— riveted wrought iron, 289
—— rolled steel, 290
—— rolled wrought iron, 285, 286
—— rules for, 284–290
—— single web, 285
—— tee, 285
—— wood, with flitch plate, 284, 293
Glands, 41, 246
Glass, cements for, 368–370
—— composition of, 386
—— strength of, 345
—— to drill, 266
—— to toughen, 365
Glass-cutters' sand for polishing metals, 259
—— weight of, 323
Gold coin, weight of, 355
—— coins, alloy for, 355
—— imitation, 247
—— solders for, 258
Governor arms, 31
—— balls, 30, 33
—— for steam engines, 29–34
Governors, centrifugal force of, 30
—— centripetal force of, 30
—— cross-armed, 31
—— pulleys for, 31
—— shifting-eccentric, 33, 34
—— simple, 30
—— speed of, 31, 33
—— spring, 31
—— weighted, 32, 33
Grain-tin, 356
Grate bars, size and weight of, 197
—— surface required for wood burning, 202
Gravers, to harden, 267
Gravity, resistance due to, 68
—— rules for, 377, 378
Grease, antifriction, 365
—— axle, 365
—— for toothed wheels, 365
Green varnish for metals, 376
Greenheart, strength of, 390
Grinding wheels, 416
Grindstones, speed of, 227
Grooves, friction of ropes in, 135
Guns, bore of, 322
—— velocity of shot, 429
Gun metal, Admiralty, 252
—— metal casting, 248
—— metal for bearings, 246–250
—— metal, strength of, 243, 253, 344, 390
—— metal, various mixtures of, 242–250
—— metal, weight of, 243, 311, 312
—— metal tubes, weight of, 337
Gusset stays, for boilers, 171
Gutta-percha, specific gravity of, 346
Gyration radius of, &c., 128

HALF-CIRCLES of cast-iron, weight of, 319
Hand-worked pumps, 101
—— working taps, 271
Hangers for shafting, 153, 155, 156
Hardened copper-tubes, 337
Hardening alloy, 254
cast-iron, 264
—— chisels, 266, 267
—— cutters, 269
— drills, 265, 267 ; gravers, 267
— hammers, 266
— metals, 261-270
— processes, 264-270
—— rhymers, 269
—— springs, 267
—— steel plates in oil, effect of, 345
— taps, 269
—— tools, 266
Hardness of metals, 359
Head for a given velocity, 353
—— of water, loss of, due to friction, 116
—— of water, pressure of, 113
Heat, absorption of, 207
—— cement to resist, 372
— -conducting power of metals, 206
effect of, on water, 167
— emission of from pipes, 214
— expansion of gases by, 206
—— expansion of liquids by, 206
—— melting, 256
—— of furnaces, 256
— radiation of, 207
— reflection of, 207
—— smelting, 216, 256
— specific, of solids and liquids, 205
—— transmitted through plates, 208
—— welding of iron, 256
Heating buildings and rooms by hot water, 209-212
— buildings and rooms by steam, 211
—— feed water, 174
—— surface of boilers, 72, 74, 175, 190
—— water, 167
—— water in tanks by steam, 214
Helical toothed-wheels, 130, 132, 133
Hematite iron, mixtures of, 241
Hemp ropes, 282, 284
—— ropes for rope gearing, 134
Hexagon nuts, Whitworth size, 305
High speed engines, 38, 430
Hire of engines, 151
—— of steam power and shafting, 151
Hollow beams, 287
—— columns and pillars, 299
—— shafts, 148
Homogeneous metal, 109, 260
Hoop gauge, B. G., 309
Hoop iron, weight of, 308
Hoops, length of angle iron to make, 312
—— length of bar to make, 312
Hornbeam, strength of, 345, 390
Horse-labour, 4
Horse-power, 5
—— absorbed by friction, 147
—— actual, 5
—— for grinding wheels, 416
— indicated, 5, 14, 38, 63, 68
—— nominal, 5
—— of Balata belts, 395
—— of belts, 163
—— of bevel wheels, 130
—— of centrifugal pumps, 104
—— of compound engines, 62
—— of Cornish boilers, 174
—— of crank shafts, 149
—— of egg-ended boilers, 174
—— of engines, 5, 434
—— of factory chimneys, 195
—— of fans, 237
—— of gearing, 131, 133, 135-145
—— of Helical toothed-wheels, 133
—— of Lancashire boilers, 174
—— of locomotive engines, 69, 71, 74
—— of mitre wheels, 130
—— of mortice wheels, 131
—— of pumps, 103
—— of rope gearing, 134
—— of shafts, 149, 150
—— of spur wheels, 131, 135
—— of toothed wheels, 131, 133
—— of vertical boilers, 175
—— of water wheels, 115
—— of wood working machinery, 220
—— required for machine-tools, 350
Horses, power of, 4
—— pulling force of, 4
—— space for in stables, 212
—— tested performances of, 428, 430
—— weight of, 4
Hospitals, space for beds in, 213
—— ventilation, 212
—— warming, 212
Hot bearings, 215
—— blast for melting iron, temperature of, 256
Hot-water boiler, 211
— heating by, 208-212
- pipes, 209, 210
—— pipes, cooling of, 210
—— pipes, length of, required to heat various buildings, 210
Hot-water pumps, 102
Hydraulic cylinders, 119
—— mean depth, 116
—— memoranda, 93-95, 118
—— pipes, 274
—— press, 119
—— press cylinders, strength of, 119
—— pressure, 120
—— rams, 104, 105
—— rules, 93, 95
—— work, gun-metal, for, 247, 250

Hydrogen gas, weight of, 293
Hyperbolic logarithms, 18

ICE, bearing power of, 94
Ice, weight of, 94
Imitation gold, 247
—— platinum, 253
—— silver, 253
Imperial standard wire-gauge, 425
—— standard wire-gauge, weight of a square foot of metals to—viz. of sheet-iron, sheet-copper, brass, gun-metal, Bessemer steel, rolled steel—white metal, zinc, lead, 309, 310, 311
—— standard wire-gauge, weight of wire to, 313
Impressions, alloy for taking, 252, 254
—— composition for taking, 364
Inclination and weight of roofs, 390
—— of drains, pipes, sewers, and rivers, 117
Incrustation in steam boilers, 197
India-rubber, cement for, 370
—— belting, 164
—— valves for pumps, 58, 101
—— weight of, 346
Indicated horse-power, 5, 14, 38, 63, 68, 71, 74
—— horse-power required to drive various machine-tools, 350
—— horse-power required to drive wood-working machinery, 220
Indicator, 8
—— diagrams, 9-15
Initial pressure of steam, 15
Injection-pipe, 56
—— water, 56
Injectors for feeding boilers, 114
Inside lap, 25, 42
Instructions to boiler-attendants, 198
Insufficient lead, 25
Interest for any number of days, to find, 421
—— table, 421
Internal flue tube of boilers, 171, 187
Iron cables and chains, 283, 284
Iron, Cast-, 406
—— —— balls, 315
—— —— beams, 281
—— —— brands of, 216
—— —— chilled, 247
—— —— circular plates of, 320
—— —— columns, 299
—— —— cylinders, 317, 318
—— —— fire-bars, 197
—— —— gearing, 123-145
—— —— girders, 287, 288
—— —— half circles of, 319
—— —— mixtures of metal for, 241
—— —— notes on, 357
—— —— pans, 316
—— —— pig, 240
—— —— pillars, 299
Iron, Cast-, pipes, 109-113
—— —— plates, 312, 320
—— —— pulleys for belts, 161
—— —— pulleys for ropes, 134
—— —— square foot of, 312
—— —— square plates of, 320
—— —— strength of, 240, 344
—— —— tests for, 240, 279-281, 360
—— —— to harden, 264
—— —— to soften, 265
Iron cables, 283
—— chains, 282
—— circular plates, 302
—— effect of reheating and rolling, 281
—— galvanized, 261, 306, 323
—— girders, 284
—— loss of strength of, at high temperature, 181
—— rivets, 300, 323
—— sheets, 302, 309, 325
—— tee, 301
—— tubes, 182, 184, 274, 305
—— wire, 308, 313, 344
—— wire rope, 283
—— castings, metals for, 241
—— castings, rules for the weight of, 295
—— annealing, 264, 265
—— blueing, 260
—— bronzing, 262
—— cements for, 373
—— colouring, 260
—— corrosion of, 360
—— galvanizing, 261
—— hardening, 264
—— japanning, 260
—— lacquer, 261
—— malleable cast, 265
—— painting, 360, 374
—— sheet and hoop gauge B. G., 309
—— softening, 264, 265
—— strength of, *see* Strength
—— tinning, 261
—— wire gauge, standard, 309, 313, 425
—— -wire gauges, Birmingham, and various other, 324
—— Wrought-, 406
—— Wrought-, viz. angle and T, 314
—— —— bar, 307, 308
—— zincing, 261

JAPANNING metals, 260
Jarrah, strength of, 390
Jet-condensers, 55, 56
Jewellers' cements, 372
—— metal, 247
—— solders, 258
Joints, cements for, 373
—— riveted, 184, 185, 186, 300, 301
—— riveted, strength of, 184-186, 301
—— with pin, 304

Joists, rolled wrought-iron, 285, 286
—— rolled steel, 289, 290
Journals, corners of, 151
—— friction of, 146, 147
—— metal for bearings of, 243-255
—— of water wheels, rule for size of, 115
—— pressure on, 151
Joy's valve-gear, 77, 78

KEYBED of eccentric, to find the position of, 28
Keys for wheels, 156: cone-keys, 159
Knuckle gear, 125

LACQUERS for brass work, 263
—— for iron work, 261
Lancashire boilers, contents of, 176
—— evaporative performance of, 190
—— boiler, horse-power, 174
—— boilers, proportions and weight of, 177
—— boilers, rules and data for, 168-177
—— rules for weight of, 182
Lap alloy, 246
—— of valve, 25, 42
—— of valve, to cut off steam by, 25
—— welded boiler shells, weight of, 183
—— welded boiler tubes, weight of, 184
—— welded tubes for gas, steam, and water, 329, 340
Latent heat, 20
—— heat of liquefaction, 206
Lathe centres, 230
—— change wheels, 233-239
—— screw-cutting, 229, 239
—— speed for turning, 217
—— speed of cut, 218
—— tool angles, 218
Lathes, power required to, 350
—— work done by, 219
Lathe-work, price of, 232
Law, notes on, 426, 427
Lead, 406
—— alloys of, 252, 253
—— bars, weight of, 321
—— of valve, 24
—— notes on, 356
—— pipes, composition, 306
—— pipes, strength of, 314
—— pipes, weight of, 314, 315
—— required for pipe joints, 316
—— sheet, strength of, 345
—— sheet, weight of, 311, 323, 325
Leaky pistons and valves, 20
Leather, cements for, 370, 372
—— belting, strength and weight of, 163
—— belts, cements for, 373
—— belts, dressing for, 366
—— belts, horse-power of, 163
—— belts, rules for, 163
Left-hand screw-threads, 236
Length of boilers, 170
—— of stroke of engines, 42
—— of stroke of pumps, 104
Letters for patterns, 255
Lift of centrifugal pumps, 104
—— of hydraulic rams, 105
—— of pumps, 99
—— of safety-valve, 192
Lightning conductors, 196
Lignum-vitae, strength of, 390
Limits of velocity in rivers, &c., 118
Line of back pressure in diagrams, 10, 12
Linen belting, 164
Links of chains, proportions of, 284
Liquefaction, latent heat of, 206
Liquid fuel, 79, 86, 169, 190, 430
—— ——, analysis of, 399
Liquids, expansion of by heat, 206
—— specific gravity of, 347
—— weight of, 347, 349
List of chemical and mineral substances, 385-387
—— of minerals, 348, 385
—— of woods, and their uses, 361
Live loads, 284, 285, 290
Load to be overcome in pump barrels, 106
Loads, live and dead, 284, 285, 290
—— working, on materials, 389, 390
Locomotive boilers, evaporation performance of, 190
—— engines, adhesive power of, 66
—— compound, 73-75
—— cylinders of, 69
—— metallic packing for piston-rods of, 41, 70, 253, 255
Locomotives, effective pressure of steam in, and various rules for, 66-71
—— express passenger engines, 71-75
—— power of, 67, 69, 71, 74
—— resistance on rails, 67
—— weight of, 72, 74
Logarithms, hyperbolic, 18
Longitudinal expansion of internal flue tube, 172
Longitudinal seams of internal flue tubes, 172
Longitudinal stay-bolts of boilers, 171
—— seams of internal flue tubes, 172
—— stay-bolts of boilers, 171
—— strain on boiler shells, 170
Lowest absolute terminal pressure, 21
Lubricant for steam cylinders, 41
Lubricating antifriction compounds, 365
—— wood-teeth of mortice wheels, 127
Lubrication, 146
Lubricator for connecting-rods, 49

MACHINE-MOULDED toothed-wheels, 135
Machine tool work, 232

Machine tool wook, cost of, 232
Machine-tools, power required for, 350
Machining Metals, 220
Machinery, depreciation of, 379
—— oils and grease, 146, 365
—— painting, 374
—— power for, 350
—— refrigerating, 215
Magnesium, 406
Mahogany, strength of, 345, 390
Malleability of metals, 245
Malleable cast iron, 265, 357
Manganese bronze, 328, 352, 390
—— steel, 330, 358, 390
Manhole of boilers, 169
Marble, to clean and whiten, 367
Marine return-tube boilers, evaporative performance of, 190
Materials, strength of, 109, 110, 131, 163
Mean annual rainfall, 433
—— effective pressure of steam, 15, 63
—— pressure of steam, 15
—— temperature of air, 432
Measures, French, 415–423
Measuring patterns, 296
—— timber, 363
Medals and medallions, metal for, 246, 250, 254
Megass fuel, 169
Melting point of metals, 256
Memel-beams, 293
—— strength of, 390
Memoranda, hydraulic, 93–95, 108
—— foundry, 246, 248, 364
Men power, of, 4
Mercury, 406
—— melting and boiling points of, 256
Metal, anticorrosive, 246, 247, 252, 255
—— anti-friction, 252, 255, 329
—— expansive, 49
—— for anvils, 241
—— for bearings, 247–255
—— for bells, 230c, 230d, 234a
—— for brass and bronze castings, special mixtures of, 247–251
—— for brass boiler tubes, 249
— for brass bolts, 249, 250
—— for bushes, 243–245
—— for chilled rolls, 231
—— for cocks and valves, 246–249
—— for cylinders, 231
— for jewellers, 247
—— special mixtures of, for iron castings, 241
Metallic packing, 41, 70, 249–255
Metals and woods, safe working stress on, 390
—— blueing and bronzing, 260–262
—— colouring, 260–262
—— conducting power of, 206, 276
—— contraction of in casting, 379
—— corrodibility, relative of, 366
—— corrosion, prevention of, 360
Metals, cutting, 216, 217, 219, 232
—— dissolving, 262, 355
—— for glands, 246
—— French weights of, 421
—— hardness of, 359
—— japanning, 260
—— lacquering, 261, 263
—— loss of strength of, by heat, 257, 281
—— polishing, 259
—— qualities of, 355–359
—— silvering, 263
—— weight of a square foot of various, 312, 325, 326–334
——, weight of a square foot of various, to the imperial standard wire gauge, 309, 310, 311, 312, 326, 331
—— white, 254, 255, 311, 325, 329, 338
Metre, French, 420
Metrical measures, 415–423
—— weights, 421
Mild steel, weight of, 311, 325
—— strength of, 359, 390
Millimetres equivalents of parts of an inch and parts of a foot, 423
—— equivalents of the Imperial Standard Wire-gauge, 313
—— pitches of screws, 238
—— pitches, change wheels for, 245
—— sizes of wire, weight to, 313
Millimetres, 415–430
scale, 414
Milling machine cutters, speed of, 217
machined work, cost of, 232
Milling-machines, power for, 350
Mill gearing, 123–145
Millwork, 123–164
Mill-race, 118
Minerals, list of, 384, 385
Mineral substances, list of, 385–387
Mines, ventilation of, 213
Mitre wheels, 124, 135
Modelling-clay, 364
wax, 364
Module cut teeth, 413
—— pitch, 407
Modulus of machines, 3
Moire metal, 264
Momentum, balancing, 38
Monel metal, 393, 410
Morse tapers, 413
Mortar, 388, 390
Mortice-wheels, 126, 131, 135
Motor-boats, 431
Motor-cars, 430
—— bearing-metal for, 249, 250
—— resistance of traction on roads, 431
Mouthpiece of boiler furnaces, 173
Movement of piston and slide valve, 23, 24
Mudholes of boilers, 173
Muff couplings, 153, 154
Mules, power of, 4
Muntz metal, 250, 327

NAVAL brass, 248, 326, 327
Naval-brass tubes, weight of, 339
Necks, corners of, 151
—— of shafts, 151, 245
Nickel, 356, 406
—— alloys, 245, 252, 253
—— -aluminium, 334
—— -bronze, 251, 328, 419
—— steel, composition and strength of, 359, 390
—— various alloys of, 252, 253
Nitrogen, 168
Nominal horse-power, 5
—— —— of boilers, 174, 175
—— —— of crank shafts, 149
—— —— of engines, 5
—— —— of leather belts, 163
—— —— of pumps, 103
Non-conducting material for clothing pipes, 120
—— -conducting material for clothing steam-cylinders, 367
—— -conducting material for covering steam-boilers, 372
Non-corrosive alloys, 247, 248, 250, 255
Nuts, lock, 304
—— rusted, to remove, 365
—— Whitworth's standard size, 305

OIL, to refine, 366
Oil paints, 360, 374
—— -less bearings, composition, 375
—— varnishes, 371
—— -engines, 79, 86
Oils and grease for engine-cylinders, 41; for machinery, 146, 365
—— weight of, 347, 349
Old brass, to melt, 213
Open streams, flow of water in, 116
Organ pipes, metal for, 254
Orifices, flow of water through, 115
Ormolu, 218
Ornamental castings, metal for, 217, 218, 250, 252, 253
Outside lap, 25, 42
Overshot waterwheels, 114
—— —— horse-power of, 115
Oxygen, 168

PACKING paper, to waterproof, 366
—— —— metallic, 41, 70, 213, 255
Paddle water-wheel, 114
Paint, flexible, 374
—— for blackboards, 374
—— for wire, 374
—— old, to remove, 360, 375
—— to prevent dry rot, 374
—— useful life of, 360
Painting iron-work, 374
Painting, machinery, 374
Paints, anti-rust qualities of, 360
Palladium, 406
Paper, sizes of, 377
—— varnish for, 376
Passenger locomotive engines, 71-75
Patents, 432
Patterns, letters for, 213
—— measuring, 296
—— metal for, 240, 242
Pattern-makers' varnish, 376
Peat, evaporating power of, 169
—— heat, bulk, weight, and composition of, 380
Percentage of carbon in steel, 268
Perforated baffle plate for boiler fronts, 173
—— pipe for feeding boilers, 174
Perforations in slide valves, alloy for filling, 255
Petrol-engines, 430
Phosphor bronze, 109, 144, 341
Physical properties of metals, 406
Pig iron, brands of, 240
—— mixtures of, 241
—— stowage of, 329
Pillars, hollow, 299
—— rules for strength and weight of, 299
—— solid, 299
Pine, pitch, red, white, yellow, strength of, 390
Pipe bends, effect of, 117
—— coverings, 120, 372
Pipes, brass, 329, 335
—— emission of heat from, 214, 215
—— expansion of, 212
—— for gas, 112, 271, 339
—— for hot water, 209, 210
—— for steam, 29, 40, 109, 112, 339
—— for water, 97, 110, 111, 117, 329
—— gun-metal, weight of, 337
—— hydraulic, 274
—— naval brass, weight of, 339
—— pressure in, 113
—— steam, condensation in, when cooled by water, 214
—— steam, heating water by, 214
—— steel, weight of, 341-343
—— white metal, weight of, 338
—— wrought-iron, weight of, 338-340
Pipes bursting pressure of, 109, 110
—— contents of, 95, 113
—— cast iron, proportions and weight of, 110-112
—— cast iron testing, 110
—— copper, 330, 336
—— delivery of pumps, 102
—— exhaust, 29, 40
—— injection, 56
—— lead, 314, 315
—— of various metals, rules for, 109
—— steam, 29, 40, 109, 112, 339
—— suction of pumps, 102
—— water, discharge of, for Town's water supply, 97, 353

Pipes, wrought iron, 182, 184, 274, 305, 339, 340
Pistons, 42, 43
—— leaky, 20
—— rings, 43
—— rings, alloy, for 43,
Piston rod, 40 ; packing for, 41, 70
—— speed, 38, 62, 70
Pitch of rivets in boilers, 300
—— of rivets in girders, 289
—— of spiral springs, 194
—— of wheel gearing, 124, 127
Pitch-pine, strength of, 390
Planing machines, feed of cut, 218
—— machines for wood, speed of, 220
—— machines, power for, 350
—— work, 219 ; cost of, 232
Plastic bronze, 250
Plate-bending machines, power for, 350
Plates, strength of, see Tensile and Compressive strength.
—— brass and copper, weight of, 310, 312
—— cast iron, weight of, 312, 320
—— of steel, 280, 281, 302, 311
—— of various metals, weight of, 312, 325,
—— tin, 312, 322
—— wrought iron, weight of, 302, 309, 325
Platinum, specific gravity of, 292
Plumbago, crucibles, 364
—— lubricants, 364
Plummer blocks, proportions and weight of, 151, 157
Point of compression, of steam, 13
—— of cut-off of steam, 11, 15, 25
Polishing metals, 259
Port, exhaust, 29, 40
—— steam, 28, 29, 40
Portable boilers, evaporatice performance of, 190
Portable-engines, hire of, 151
Portable engine boilers, proportions and weight of, 180
—— engine boilers, rule for weight of, 182
Position of feed in boilers, 174
Pot-metal, 246
Power absorbed by friction, 146
—— and weight of men and animals, 4
—— of belts, 162, 163
—— of boilers, 175
—— of crane gearing, 131
—— of crank shafts, 149, 151
—— of engines, 5, 69, 74
—— of factory chimneys, 195
—— of frictional gearing, 133
—— of fuels, 169, 380
—— of gas, 381
—— of gearing, 130, 131, 135
—— of governors, 30
—— of horses, 4
—— of leather belts, 393, 394
—— of pumps, 103
—— of rope gearing, 134
Power of shafts of wrought iron, cast iron, and steel, 150
—— of water, 114
—— of water-wheels, 115
—— of wheel gearing, 130, 131
—— of wind on railway structures, 382, 383
—— for refrigerators, 215
—— for wood-working machinery, 220
—— of wire-rope gearing, 164
—— required to drive various machine-tools, 350
—— required for machine tools, 397
Press, hydraulic, 119
Pressure conversion, 418
—— in pipes, 113
—— of gas, 381
—— of steam, 15
—— of water, 94, 98, 113
—— of wind, 382, 383, 390
—— on necks of shafts, 151, 245
Prevention of scale in steam boilers, 197
—— of the corrosion of metals, 360
Price of drilled work, 232
—— of fitter's work, 232
—— of hired steam-power, 151
—— of lathe work, 232
—— of machined work, 232
—— of planing work, 232
—— of turning work, 232
—— selling, of goods, 431
Producer-gas, 79
Production and conversion of steel, 358
Profit and discount table, 421
Properties of air, 422
—— of aluminium, 400
—— of duralium, 401
—— of magnesium, 402
—— of saturated steam, 16, 17
Pulleys, cementing leather on, 373
—— for belts, 158-162
—— for rope gearing, 134
—— for rope gearing, weight of, 134
—— weight of, 161
—— with curved arms, 169
—— with straight arms, 159, 160
—— wood, friction on, 164
—— wood, power and weight of, 162
—— wood, to harden, 367
Pulling force of animals, 4
Pump suction and delivery pipes, 102
—— barrels, load to be overcome in, 106
—— well-frames, 102
Pumping engines, speed of, 105
Pumps, 98-108, 352, 353
—— air, 55-58
—— air vessel for, 99, 103
—— capacity of, 98, 103, 113
—— centrifugal, 104
—— diameter of, 104
—— discharge of, 103, 107, 108, 353
—— effective work of, 104

Pumps, feed, 45 :—— force-, 102
— — for hand-power, 101
— - for hot water, 102
— - gun-metal for, 230c, 230d, 250
Pumps, horse-power of, 104
-— lifting, 98
load on, 98, 101, 102, 106
– resistance, of 102, 103
—— speed of, 115 : —— valves for, 100
Punch, compressive strength of a, 378
Punching machines, power for, 350
plates, loss of strength by, 185
- – power required for various metals, 378

QUALITIES of metals, 355-359
—— of timber, 362, 363
Quantity of solder required for pipe-joints, 314
— of water delivered by pipes, 97, 116
— of work turned out by machine-tools, 231

RADIATION of heat, 207
Rails, resistance on, 4, 66
Railway wheel lathes, power for, 350
Rain-water, purification of, 96
Ram, hydraulic, 104, 105
—— of pump, 103
Ratio of expansion, 15, 21, 62
Reflection of heat, 207
Refrigerating machinery, 215
Relative volume of steam, 15
Relief-frame for slide valves, 27
Remedies for accidents, 437-439
Reservoirs for cooling water, 56
Resistance of pumps, 102, 106
- of trains, 67
of weights to dragging, 5
to collapsing, 187
to friction, 146
to tearing, 185
Return tube boilers, 181, 190
Rhymers, to harden, 269
Richard's indicator, 9
Rings, strengthening, for boilers, 172
Rivers, flow of, 116
Riveted girders, 289
- joints in soft steel-plates, 301
— steel pipes or tubes, 342, 343
Rivets, brass, alloy for, 249
- - copper, alloy for, 250
—— copper, weight of, 323
- iron, weight of, 323
proportions of, 300
pitch for girders, 289
Rolled brass, 250, 310
— copper, weight of, 310
iron joists, 285
— steel joists, safe loads on, 290
— steel, weight of, 302, 309, 311
white metal, 311
Rolls, chilled metal for, 247
Rolls, metal for bearings of, 251, 252
——, turning, 217, 219
Romanium, 334
Roofing, sheet-iron for, 306, 390
Roofs, height of, and weight on, 390
Rope-belts, 135
- —— -gearing, 133, 134
— – ——, horse-power of, 134
Ropes, 282-284
— — for rope-gearing, 134
— friction of, in grooves, 135
-- – friction of, on pulleys, 164
Rust, joint, cement, 373
—— preserving metals from, 360, 365

SAFE tortional strength of shafts, 147
Safety-valves, 190-193
—— -valve springs, 193, 194
Salt water, 90, 202
Sand for polishing metals, 259
Saturated steam, 168
Saw-benches, 220
Saws, band, 220
Scale in boilers, 197
Screw threads, 240, 270-276
Screws and bolts, 275, 303
—— for wood, 315
Screw propellers, metal for, 248, 249
Screwing bolts, 219
- —— tackle, 271, 272
Sea water, composition of, 202
—— — — weight of, 94
Setting boilers, 173
Sewage, flow of, 119
—— pipes, discharge of, 119, 354
Shafts crank, 43, 149, 152
— — for cranes, 149
—— friction of, 146
-- – hollow, strength of, 148
—— lifting heavy weights, 149
Shafting, collars for, 152
—- distance of bearings of, 150
—— hangers for, 153, 155
speed of, 151
-- tortional strength of, 147
weight of, 152
Shaping machines, 219 : power for, 350
Shearing, iron, 378, 379
Sheet-gauge, B. G., 309
— - iron, galvanized, 323
— - tin, 312, 322
— - zinc, 311, 312, 322
Shell of boilers, 169, 173
Ship plates, strength of, 279
—— plates, test for, 280
Shortness of water in boilers, 199
Siemens-steel, 358
Silicon-bronze, 253, 328
Silver, 406
Sizes and weights of tin plates, 322

Slag, composition of, 387
Slide bars, 47
—— block, 46
—— valve, friction of, 27
—— valve, lap of, 25, 42
—— valve, lead of, 24
—— valve, metal for, 246-248
Slot drilling work, 219
Slotting machines, power for, 350
—— work, 219
Smelting, cupola, 216
—— heat, 258
Snow, mixtures of, for freezing, 367
Socket pipes, 110, 111
Softening metals, 265
Solder for aluminium, 258
Solders for brass, 258
—— for copper, 258
—— for iron, 258
—— for lead, 257
—— for steel, 258
—— for tin, 257
Specific gravity, 346, 347
—— heat, 205
Speed for cutting metals, 217
—— of air-pumps, 58
—— of circular saws, 220
—— of conveyances, 430
—— of engines, 38, 424
—— of gearing, 125, 129
—— of governors, 31, 33
—— of grindstones, 237
—— of lathe work, 217
—— of piston, 38, 62, 70
—— of pulleys, rules for, 158
—— of pumps, 105
—— of rope gearing, 134
—— of saws for metals, 218
—— of saws for wood, 220
—— of shafting, 151
—— of water-wheels, 114
—— of wheel gearing, 125, 129
—— of wood-working machinery, 220
Spelter, 252
Sphere, hollow, strength of, 174
Spherical shell, strength of, 187
Spiral springs, rules for, 193, 194
Spring governor, 31
Springs, compression of, 194
—— extension of, 194
—— for safety valves, 193, 194
—— hardening and tempering, 267
—— plate, 194, 195
—— spiral, 193, 194
—— strength of, 193, 194
Sprocket-wheels and chain, 130
Spur-wheels, proportions of, 124
Standard pipe flanges, 403, 404
Staying flat surfaces, 173, 174
Steam, 9-22, 167, 168
—— boilers, 167-190
—— compression of, 21, 28
Steam, condensation of, in pipes cooled by water, 214
—— cylinders, 38, 109
—— cylinders, strength of, 109
—— engines, proportions of, 36-70
—— engines, cost of working, 79
—— exhaust, 12, 21, 29
—— heating rooms by, 211
—— heating water by, 211
—— jacket, 22, 23
—— joints, cements for, 373
—— line of diagrams, 11
—— pipes, covering for, 120
—— pipes, weight of, 112, 339
—— ports, 28, 29, 40
—— power, hire of, 151
—— pressure, 15
Steel blister, 358
—— cast, 358
—— castings, 135
—— girders, safe loads for, 291, 292
—— joists, safe loads for, 289, 290
—— joists used as stanchions, crushing load on, 293
—— wire, 308, 344
—— wire ropes, 282
Stone, working loads on, 389
Strain at pitch line of wheels, 132
—— on boiler shells, 170
—— on bolts, 301
—— on gearing, 131, 132
—— on ropes and chains, 282-284
—— on shafts and shafting, 147
Straw as fuel, 169, 380
—— bulk of, 348
Strength of aluminium, 331
—— of aluminium alloys, 253
—— of angle and tee iron, 314
—— of antimony, 345
—— of ash, 315, 380
—— of beams, 284-289, 293
—— of belting, 163, 164
—— of Bessemer Steel, 280, 314
—— of bismuth, 345
—— of blister steel, 344
—— of boilers, 187-190
—— of bolts, 304
—— of cast steel, 135, 344
—— of columns, hollow, 299
—— of columns, solid, 299
—— of compressed bronze, 244
—— of copper tubes, 337
—— of cotton belting, 163, 345
—— of crane gearing, 131
—— of crane shafts, 149
—— of crank shafts, 149, 151
—— of cylinders, hydraulic, 119
—— of flat surfaces in boilers, 173, 174
—— of furnace tubes, 187
—— of gearing, 130, 132, 135
—— of girders, 284-295

Strength of glass, 345
—— of granite, 345
—— of helical toothed-wheels, 132, 133
—— of hemp, 345
—— of hemp rope, 282, 284
—— of hollow columns, 299
—— of hollow shafts, 148
—— of ice, 94
—— of joints, riveted, 184–186, 301
—— of joists, iron, rolled, 285
—— of joists, steel, rolled, 290
—— of lead, 345
—— of lead pipes, 314
—— of leather-belts, 163, 315
—— of lignum-vitæ, 345, 370
—— of rolled joists and girders, 285, 286, 290
—— of rope-belts, 134
—— of ropes, 282–284
—— of shafts, crane, 149
—— of shafts, crank, 149, 152
—— of shafts, hollow, 148
—— of sheer-steel, 311
—— of shell of boilers, 187-188
—— of ship plates, 279
—— of spring steel, 314
—— of springs, laminated, 194, 195
—— of wire, 313, 314
—— of wood, 345, 390
Stroke, length of, of engines, 42
—— length of, of pumps, 104
Stuffing box, 40, 41
Suction pipe of pumps, 102
—— gas-producers, 79–82
—— rose of, 107
Super-heated steam, 168
Surface-condensers, 57
Surfacing metal work, 219

TACKLE, screwing, 271, 272
Tanks and cisterns, 351, 352
—— capacity of, 415
Tapers, morse, 413
Tapping-nuts, 231
Taps, British Association gauge, 270
—— gas thread, 273
—— for hydraulic and water pipes, Whitworth's standard size, 274
—— for screwing machines, 272
Tee-iron, strength of, 344
—— weight of, 314
Tee-steel, weight of, 316
Teeth of crab-wheels, 124
—— of double helical wheels, 132, 133
—— of frictional gearing, 133
—— of wheels, breaking strain of, 131
—— of wheels, friction of, 130
—— of wheels, strain at a pitch line, 132
—— of worm wheels, 125, 127
Temperatures of furnaces, 73, 256
Tempering processes, various, 264–270
—— cutters, 270
—— taps, 269
—— tools, 247
Tensile strength of aluminium, 331
—— aluminium-bronze, 243, 344
—— strength of angle and Tee-iron, 344
—— strength of brass wire, 250, 344
Tensile strength of compressed bronze, 250
—— strength of copper, 249, 253, 344
—— strength of copper wire, 344
—— strength of phosphor bronze, 244, 344
—— strength of rails, 344
—— strength of steel, 280, 344
—— strength of steel wheel castings, 135
—— strength of steel wire, 344
—— strength of tin, 344
Testing bridge plates, 281
—— cast-iron, 110, 240
—— cast-iron pipes, 110
—— iron boiler plates, 280
—— iron ship plates, 280
—— steel boiler plates, 280
—— water, 365
Thermal properties of metals, 393
—— —— of solids, 405
Thickness of metal for cylinders, 109, 119
Timber measuring, 343
Tin, 406
Tinman's solder, 257
Tinning processes, 261
Tools, angle of cutting edges, 218
—— machine, power required for, 350
—— for working wood, 220
—— work done by, 219
Toothed wheels, 123
—— helical, 133
—— friction of, 130
—— wheels, metal for, 247
Torsion, resistance to, 147, 148
Traction, resistance to, 4, 67, 431
Tractive effort of locomotives and trains, 71
—— force of locomotive engines, 67, 71
Train resistances, 66, 71
Triple-expansion engines, 64, 65
Tubes, internal flue, for boilers, 171, 172
—— aluminium, weight of, 332
—— block-tin, weight of, 306
—— brass, weight of, 329, 335
—— copper weight of, 320, 326
—— galvanized, 339
—— gas, weight of, 305, 329
—— gun-metal, 327
—— steel, weight of, 341–343
—— surface of, 424
—— white-metal, weight of, 338
Tubular boilers, 179, 190
Tungsten, 406
Turbines, rules for, 118
Twist drills, speeds for, 217

UNDERSHOT water-wheels, 114
—— water-wheels, horse-power of, 115
Unit of heat, 205
—— of power, 5
—— of work, 3

VACUUM in condenser, 56, 57
—— line of perfect, 13
Valve slide, 24-26, 42
—— —— lap of, 25, 42
—— —— lead of, 24
—— spindle, 41
—— springs, 193, 194
Valve-gear , various forms of, 75-78
Valves, leaky, 20
—— safety, 190-192
Vapours and gases, 207, 293
Varnishs for metal, 251, 253
—— for wood, 374-376
—— oil, 374
—— spirit, 375
Varnishes, composition of, 374, 375
Velocity, angular, 128
—— of governors, 31, 33
—— of streams, 117
—— of tides, 429
Ventilating furnaces, 213
Ventilation, 212, 213
—— of apartments, 212
—— of buildings, 212
—— of hospitals, 212
—— of mines, 213
—— of public rooms, 212
Vertical boilers, chimneys for, 179
—— evaporative performance of, 190
—— boilers, proportions of, 178, 179
Volume of steam, 167, 15

WARMING apartments, 210
—— apparatus, 208
—— buildings, 210
—— by hot water, 208-209
—— by steam, 211, 214
—— conservatories, 210
—— factories, 210
—— greenhouses, 210
—— horticultural forcing houses, 210
Warming laundry dry rooms, 210
—— schools, 210
Washers, weight of, 303
Water, capacity of, 93, 94
—— cisterns and tanks, 351, 352
—— column of, 94, 98, 106, 113
—— cooling, 56, 214
—— cylinders, strength of, 109, 119
—— discharged by orifices, 115
—— driving power of, 114
—— effect of heat on, 167
—— evaporation of, 169, 175, 190, 380
—— expansion of, by heat, 202
Water, for condensing engines, 56
—— heating by steam, 214
—— measures of, 93, 94
—— power, 114
—— -proofing brick walls, 366
—— -proofing cloth and leather, 366
—— tests for, 365
—— tubes boiler, 189, 190
—— velocity of, 117, 353, 425
—— weight of, 93, 94, 106
—— wheels, horse-power of, 115
—— wheels, shaft journals for, 115
—— wheels, undershot, 114
Weight and capacity of water, 93-95
—— and specific gravity, 346, 347
—— and capacity of air, 213
—— of angle iron, 314
—— of angle steel, 316
—— of bars round and square of steel, 307
—— of bars round and square of zinc, 321
—— of bells, 253
—— of belts, 163
—— of Bessemer steel, 311, 325
—— of bevel wheels, 135
—— of block-tin tubes, 306
—— of boiler flue tubes, 184
—— of boiler shells, 183
—— of boilers, 177-182
—— of boilers, rules for the, 182
—— of bolts and washers, 303
—— of brass and copper wire, 321
—— of brass bars, 321, 237
—— of brass sheets, 310, 325
—— of brass tubes, 329, 335
—— of brass wire, 321
of bricks, 389
—— of bronzes, 328
—— of building materials, 388
—— of coal and coke, 380
—— of copper sheets, 310, 325
—— of copper wire, 321
—— of couplings, muff, 154
—— of cylinders, cast-iron, 317, 318
—— of engines, 34, 36, 60, 72, 74
—— of fire-bars, 197
—— of flange couplings, 153
—— of flat iron and steel, 308
—— of flywheels, 50
—— of fuels, 380
—— of gas fittings, 305
—— of gas tubes and pipe, 305, 329
—— of galvanized sheet iron, 306, 323
—— of galvanized wire, 313
—— of gearing, cast-steel, 135
—— of gearing, rope pulleys, 134
—— of girders and joists, iron, 286
—— of glass, 323
—— of gun-metal tubes, 337
—— of half-circle of cast-rion, 319
—— of hexagon steel, 318
—— of iron ; wrought, flat, 308

Weight of iron, wrought, round, 307
—— of iron, wrought, square, 307
—— of joists and girders, iron, 286
—— of Lancashire boilers, 177, 182
—— of lead pipes, 314, 315
—— of manganese bronze, 328
—— of metal required for castings, 241
—— of Muntz-metal, 327
—— of naval-brass, 326, 327
—— of nickel-aluminium, 334
—— of nickel-bronze, 328
—— of nickel-steel, 330
—— of oval steel, 308
—— of pipes, brass, 329, 335
—— of pipes, cast-iron, 111, 112
—— of pipes, copper, 330, 336
—— of pipes, flange, 111, 112
—— of pipes for gas, 305–306
—— of pipes for steam, 112, 339
—— of pipes for water, 111
—— of pipes, lead, 314, 315
—— of pipes, socket, 111
—— of pipes, steel, 341–343
—— of pipes, wrought-iron, 182, 184
—— of plates, cast-iron, 312, 320
—— of plates for boilers, 302, 309
—— of plummer blocks, 157
—— of portable engine boilers, 180, 182
—— of pulleys for belts, 161, 162
of pulleys for ropes, 134
of return tube boilers, 181
—— of rivets, copper, 323
of rivets, iron, 323
of rolled brass, 310, 325
of rolled copper, 310, 325
—— of rope pulleys, 134
—— of ropes, hemp, 282
—— of shafting, 152
—— of sheet-brass, 310, 312
—— of sheet-copper, 310, 325
—— of sheet-lead, 311, 312
—— of sheet-steel, 302, 309
—— of square bars of zinc, 321
—— of square brass bars, 321
—— of square cast-iron plates, 320
—— of square foot of various metals, 309
—— of steam, 16, 17
—— of steam required to heat water, 214
—— of steam-engines, 34, 36, 60
—— of steam-pipes, 112, 339
—— of steel, 302, 307
—— of steel wheels, 135
—— of steel wire, 308
—— of Tee-iron, 314
—— of tin plates, 322
—— of tubes, copper, 330
—— of tubes, gun-metal, 337
—— of tubes, naval-brass, 339
—— of tubular boilers, 179
—— of vertical boilers, 178, 179
—— of white metal, 311, 329
Weight of zinc bars, 321
—— of zinc sheets, 311, 322
Welded joints, 326
Well frame, 102
Wells, contents of, 113
Wheel-cutting, 227, 350
—— -cutting, cost of, 232
—— -gearing, steel, 135
—— -keys, 156
—— -teeth, 123, 124
Wheels, metal form, 241, 249
White deal, strength of, 390
—— metal-alloys, 254, 255
—— metal, stowage capacity, 349
—— metal strength of, 253
—— metal tubes, weight of, 328
—— metal, weight of, 325, 329
Whitworth's gas threads, 273, 274
—— screw threads, 271–274
—— compressed-steel shafts, 148, 359
—— screw threads for watchmakers, 276
—— standard nuts, 305
Wind, pressure of, 383, 390
——, pressure on structures, 382, 383
Wire, millimetre sizes, weight of, 313
Wire-gauge, imperial standard, the, 313, 425
—— weight of one square foot of metals to, viz.: of sheet-iron, sheet-copper, sheet-brass, Bessemer steel, rolled steel, gun-metal, white metal, zinc, lead, 309, 310, 311, 326, 331
Wire-gauge, Birmingham, Stubs, American, French, 321
—— imperial standard, millimetre, equivalents of, 313, 425
Wire, brass, 321, 344
—— copper, 321, 344
—— iron, 290, 308 313, 344,
—— iron, sizes, weight, and breaking, strains of, according to the imperial standard wire gauge, 313
—— paint for, 374
—— -rope gearing, rules for, 164
—— steel, 308, 344
Wolframinium, 334
Wood brake-blocks, friction of, 78
Wood fuel, 169, 202
—— fuel, grate surface, and furnace area for, 202
pulleys, 162
screws, size of, 315
—— stains, 376
—— strength of, 345, 373
—— teeth of wheels, 126, 127
Wood and timber, notes on, 361–363
Woods, list of, and their uses, 361
—— safe working tensile stress and crushing stress on, 390
Wood-working machinery, 220
Work accumulated in a moving body, 378
—— done by tools, 219
—— done by tools, cost of, 232

Working load of chain slings, 398
Working loads on metals and woods, 390
—— loads on the foundations of walls, 389
Workshop accidents, remedies for, 483, 436
—— depreciation, 379
—— machinery and tools, power for, 220, 350
—— receipts, 364-367
Worm-wheels, delineation and speed of, 125
—— friction of, 130
—— proportions of, 127
Wrought-iron, 357, 390
—— -iron pulleys, 162
—— -iron, strength of, 279, 290
—— -iron tubes, weight of, 338-340

ZIGZAG riveting, 300
  Zinc, 406
Zinc, to tin, 261
—— bars, round, weight of, 321
—— bars, square, weight of, 321
—— -bronze, 252
—— notes on, 356
—— sheets, weight and gauges of, 311, 322
—— weight of, 311, 321, 322
Zinking, 264

THE END.

THE LONDON AND NORWICH PRESS, LIMITED, ST. GILES WORKS, NORWICH